Reviews

REVS. 1850-2397 VOL. 11, NO. 6 JUNE 1958

GENERAL

Theoretical and Experimental Methods. 262
Mechanics (Dynamics, Statics, Kinematics) 267

MECHANICS OF SOLIDS

Servomechanisms, Governors, Gyroscopics 271
Vibrations, Balancing..... 276
Wave Motion in Solids, Impact..... 280
Elasticity Theory..... 280
Experimental Stress Analysis..... 284
Rods, Beams, Cables, Machine Elements. 285
Plates, Disks, Shells, Membranes..... 289
Buckling Problems..... 293
Joints and Joining Methods..... 294
Structures 294
Rheology (Plastic, Viscoplastic Flow) 298
Failure, Mechanics of Solid State... 299
Mechanical Properties of Specific Materials 299
Plasticity, Forming and Cutting..... 299

MECHANICS OF FLUIDS

Hydraulics; Cavitation; Transport..... 299
Incompressible Flow: Laminar; Viscous.. 301
Compressible Flow, Gas Dynamics..... 304
Wave Motion in Fluids..... 310
Turbulence, Boundary Layer, etc..... 312
Aerodynamics of Flight; Wind Forces.. 314
Aeroelasticity (Flutter, Divergence, etc.). 314
Propellers, Fans, Turbines, Pumps, etc... 314
Flow and Flight Test Techniques..... 314

HEAT

Thermodynamics..... 316
Heat and Mass Transfer..... 318
Combustion 324

MISCELLANEOUS

Acoustics 324
Ballistics, Detonics (Explosions)..... 326
Soil Mechanics; Seepage..... 326
Micromeritics..... 326
Geophysics, Meteorology, Oceanography..... 328
Lubrication; Bearings; Wear..... 328
Marine Engineering Problems..... 329

Letters to the Editor, 329
Books Received, 329

A Review of Some Recent Studies of the Mechanical Behavior of Granular Media, H. Dereslewicz, 259

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Southwest Research Institute with the co-operation of Linda Hall Library.

APPLIED MECHANICS Reviews

Under the Sponsorship of

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS • THE ENGINEERING FOUNDATION • SOUTHWEST RESEARCH INSTITUTE • OFFICE OF NAVAL RESEARCH • AIR FORCE OFFICE OF SCIENTIFIC RESEARCH, (ARDC) • NATIONAL SCIENCE FOUNDATION

Industrial Subscribers

AMERICAN MACHINE AND FOUNDRY COMPANY • THE BABCOCK & WILCOX COMPANY • BORG-WARNER CORPORATION • CATERPILLAR TRACTOR COMPANY • FORD MOTOR COMPANY • GENERAL DYNAMICS CORPORATION • GENERAL MOTORS CORPORATION • M. W. KELLOGG COMPANY SHELL DEVELOPMENT COMPANY • STANDARD OIL FOUNDATION, INC. • UNION CARBIDE CORPORATION • UNITED AIRCRAFT CORPORATION UNITED SHOE MACHINERY CORPORATION • WESTINGHOUSE ELECTRIC CORPORATION • WOODWARD GOVERNOR COMPANY

EDITOR Martin Goland

EDITORIAL ADVISORS H. L. Dryden T. von Karman S. Timoshenko

EXECUTIVE EDITOR Stephen Juhasz

ASSOCIATE EDITORS H. Norman Abramson P. M. Ku J. C. Shipman K. Washizu

ASSISTANT EDITORS D. Callan S. Gardiner L. Graf S. Lechtman F. Salinas D. Wick

PUBLICATIONS BUSINESS MANAGER S. A. Tucker

OFFICERS OF ASME J. N. Landis, *President* E. J. Kates, *Treasurer* O. B. Schier, II, *Secretary*

AMR MANAGING COMMITTEE R. B. Smith, *Chairman* N. M. Newmark W. Ramberg R. E. Peterson E. Haynes H. Vagtborg J. M. Lessells F. J. Weyl

Editorial Office: **APPLIED MECHANICS REVIEWS, Southwest Research Institute, 8500 Culebra Road, San Antonio 6, Texas, U. S. A.**
Subscription and Production Office: **The American Society of Mechanical Engineers. 29 West 39th St., New York 18, N. Y., U. S. A.**

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: Photocopy or microfilm copies of all articles reviewed in this issue will be provided on request whenever possible. Orders should specify the APPLIED MECHANICS REVIEWS volume and review number; should be addressed to LINDA HALL LIBRARY, 5109 Cherry St., Kansas City 10, Mo., and be accompanied by a remittance to cover costs. Where desirable, photocopies and microfilm may be obtained by teletype, using the number KC334 (call numbers of LINDA HALL LIBRARY). Photocopy costs are 35c for each page of the article photocopied; minimum charge $1.25. Microfilm costs include service charge of 50c per article, plus 3c per double page; minimum order, $1.25. (*Applicant assumes responsibility for questions of copyright arising from this copying and the use made of copies. Copyright material will not be reproduced beyond recognized "fair use" without consent of copyright owner.*)

APPLIED MECHANICS REVIEWS, June 1958, Vol. 11, No. 6 Published Monthly by the American Society of Mechanical Engineers at 20th and Northampton Streets Easton, Pa., U. S. A. The editorial office is located at the Southwest Research Institute, San Antonio 6, Texas, U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Price $2.50 per copy, $25.00 a year. Changes of address must be received at Society headquarters seven weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-Laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publications (B13, Par. 4) . . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton, Pa. under the Act of March 3, 1897. ©Copyrighted, 1958, by The American Society of Mechanical Engineers.

APPLIED MECHANICS REVIEWS

VOL. 11, NO. 6 MARTIN GOLAND *Editor* JUNE 1958

A REVIEW OF SOME RECENT STUDIES OF THE MECHANICAL BEHAVIOR OF GRANULAR MEDIA

H. DERESIEWICZ

DEPARTMENT OF MECHANICAL ENGINEERING, COLUMBIA UNIVERSITY, NEW YORK

THE scope of this survey is limited to materials consisting of discrete, elastic granules in direct contract. A unit volume of such materials will consist, in part, of the solid granules and, in part, of interstitial voids. The voids may be filled with gas or liquid and the granules may be free to displace relative to one another, or the voids may contain some binding material which holds the individual particles in more or less fixed positions.

The importance of granular materials lies in their widespread occurrence and the manifold uses to which they are put in a variety of technological fields. At the same time, the diversity of fields brings with it a diversity of problems. Thus, for example, problems of determining the static pressure exerted by a granular mass occur in soil mechanics and in the design of grain storage silos; problems of propagation of elastic waves through a granular medium arise in seismological studies and in connection with petroleum prospecting; problems of vibration of such a medium, in connection with the operation of the carbon granule microphone; problems of hydrodynamics and aerodynamics, in the analysis of the movement of petroleum, ground water, and natural gas through sand, in studies of seepage, drainage, and filtration, and in questions pertaining to combustion in solid fuel beds; problems of geometry of packing of granular aggregate, in the prediction of optimum qualities, including strength, of such products as asphalt, refractories, ceramics, and grinding wheels.

Attention herein will be confined to problems of the response of granular media to external forces, that is, of the deformation and vibration of such media and of the propagation of elastic waves through them. The difficulties inherent in the solution of these problems are due to the fact that such media, while sharing many properties with solids and with fluids, cannot properly be classified as either of these states.

Most of the early analytical work, particularly in soil mechanics, was based on a representation of the material by means of a continuous model subject to additional conditions of constraint, such as the Coulomb condition that the inclination of the traction on any internal surface to the normal cannot exceed the angle of friction. An attempt at refinement of such analysis would logically start with a theory in which the model conformed more closely to reality. Thus, a natural step in this direction was undertaken by replacing the continuous model by one in which account was taken of forces transmitted between the individual granules of the array. Initial work along these lines approximated the granules by rigid spheres, and was guided by Reynolds' principle of dilatancy.

It was only some twenty years ago that the first investigation appeared in which the granules were assumed to be elastic. Thus, Hara (1),* seeking to predict the behavior of the carbon microphone, studied the propagation of compressional waves through an aggregate of like spheres arranged in simple cubic and face-centered cubic arrays. Replacing the granules by a series of mass-spring systems in series, and computing the stiffness of each spring on the basis of Hertz's theory of contact, he arrived at the result that the magnitude of the phase velocity of long waves propagating along a principal direction of the lattice is proportional to the sixth root of the normal contact force.

Rudimentary though Hara's investigation may have been, it nevertheless set the tenor of most subsequent work in this field. An extension of his analysis by Iida (2) to the case of a vertical columnar array of spheres compressed by its own weight led to the result that the phase velocity is proportional to the sixth root of the height of the column, independent of the size of the spheres, and increases with the density of the array. Experimental work by the same author (2), (3) verified the "sixth-root" dependence and the decrease in velocity with increasing porosity, but indicated a slight rise in velocity with increasing grain size.

A generalization of the foregoing theory was undertaken by Takahashi and Satô (4) who, with a view to seismological applications, discussed the velocity of elastic waves in systematic, homogeneous packings of like spheres. By using Hertz's theory they succeeded in deriving, for long waves, a secular determinantal equation yielding, in general, three values of the phase velocity, the magnitude depending on the direction of propagation. A formal analogy with an aeolotropic continuum could then be established.

Proceding in a similar vein, Gassmann (5) approximated the earth's crust as an array of like spheres in a hexagonal close-packing. When subjected only to its own weight, and when the stiffnesses at the individual contacts were computed on the basis of the Hertz theory, this array was shown to have

*Numbers in parentheses refer to references at the end of the article.

elastic constants appropriate to a continuum with transverse isotropy. Once again, three distinct wave velocities were found, each proportional to the sixth root of the depth below the surface. For a disturbance propagating along the depth (a principal direction) of such a system whose interstices are filled with a liquid, the computations indicate a compressional velocity which is higher than that for a system whose voids are filled with air, and, moreover, which does not tend to zero at the surface of the medium.

Considerable experimental work was performed to determine the variation of velocity with pressure and fluid content, particularly in materials of interest to geophysicists. Data obtained by Hughes and his coworkers (6), (7), (8) indicate that the relationships are complex and not easily reducible to empirical formulas valid over a large range of the variables. Results of experiments on compressional waves in dry sand, reported by Matsukawa and Hunter (9), are in agreement with Gassmann's theoretical predictions, but reveal a sensitivity of the phase velocity to grain size.

All the investigations discussed thus far are based on models of the medium composed of like spheres in regular arrays. While such restrictions, and the resulting simplification, are advisable in the course of initial exploration of this complex field, the conclusions which may be drawn on the basis of such theories can be expected to have only qualitative significance when applied to real materials.

The abandonment of the regular lattice served as the starting point for a study by Brandt (10). He considered a model consisting of several sets of like spheres, the spheres in a given set fitting in the interstices of the preceding set. The ratio of radii of the spheres in successive sets was taken to be very small, so that each set of spheres could be assumed packed randomly and unaffected by the presence of boundaries. The remaining voids were filled with liquid under pressure, and the entire system enclosed within flexible walls capable of transmitting external pressure. Availing himself of the Hertz theory of contact, the author derived expressions for the energy required to compress the assemblage, the elastic energy stored in the granules, and the energy in the compressed liquid. Then, applying the principle of conservation of energy, and introducing empirical values for the porosity of a random packing and the corresponding average number of contacts per sphere, he arrived at an expression for the phase velocity of pressure waves in such a medium. Extension to an analogous model containing nonspherical particles was made by the introduction of an additional empirical, shape-dependent parameter.

In common with the work discussed above, Brandt's theory predicts proportionality of the speed of a pressure wave in a dry aggregate to the sixth root of the external pressure, a result essentially verified, for low values of the pressure, in experiments by Hughes and Kelly (8) and Nasu (11). At higher pressures, experiments by the former indicate a less rapid variation of the velocity; the point of transition between the behavior at low and high pressures is conjectured to be the limit beyond which excessive increase in contact area invalidates the Hertz theory. Two further results of the theory, the first indicating a slight decrease of porosity due to an increase in pressure, the second predicting a linear relation between bulk volume and the two-thirds power of the pressure, agree with observations made by Fatt on granular media found in nature (12) and on laboratory models (13), respectively. One other conclusion of Brandt's theory may be cited, namely that, for a given value of the external pressure, the speed of a sound wave is decreased by an increase in the pressure of the interstitial fluid.

While the success of some of the foregoing theoretical analysis has been noteworthy in obtaining qualitative agreement with observations, such agreement on a quantitative level has often been less than satisfactory. Thus, for example, the various theories predict phase velocities proportional to the sixth root of the external isotropic pressure and to the cube root of the elastic modulus, a conclusion essentially substantiated experimentally, but the magnitude of these velocities is smaller than of the actual ones. It appears, then, that a reexamination is called for of the assumptions made and possible factors omitted in each of the models on which the analysis was based.

In a real granular aggregate subjected to an external disturbance, be it static or dynamic, the contact surfaces of the individual particles are subjected to local forces which, in general, vary both in direction and in magnitude. In addition, twisting couples may appear at the contacts. Due to the fact, however, that the several investigations were based solely on the Hertz theory of elastic contact, the effects of only the normal components of contact forces have been accounted for. The reason for the omission of the other factors has been the unavailability, until recently, of solutions of the equations of elasticity corresponding to contact due to oblique forces and twisting couples.

The inclusion of these additional factors in the theory may be expected to produce significant corrections since, even in the simplest case of oblique contact, the stiffness of a contact in a tangential direction is of the same order of magnitude as its stiffness in the direction of its normal. The improvement of the theory is, however, attended by mathematical complications which stem from the fact that the tangential load-displacement relations are, in general, not only nonlinear (as is the corresponding Hertz relation) but, as was shown by Mindlin and Deresiewicz (14), inelastic as well. Accordingly, the response of the aggregate is dependent upon the history of loading, and stress-strain relations for the medium must be expressed in incremental form.

Work incorporating some of these ideas has, thus far, been confined to the analysis of models comprised of like spheres in regular arrangements. This is due to a desire to effect a simplification, and also because a good first approximation to the structure of many real granular media, as manifested by the porosity, can be achieved by appropriate mixtures of clusters of regular loose (e.g., simple-cubic) and dense (e.g., face-centered cubic) packings of spheres (15).

The process by which the incremental stress-strain relations are obtained consists of computing the deformation, and by means of it the strain, of a unit volume of the medium, which result from the presence of incremental forces at the contacts. These contact forces, in turn, are expressed in terms of the applied incremental stress. The procedure was applied to the simple-cubic lattice under an arbitrary initial load and subjected to an arbitrary additional, incremental load (16). Subsequently the incremental relations were integrated for a loading history yielding homothetic states of stress, and the resulting total stress-strain relations employed in analyzing the compression of the lattice by forces parallel to one of its face diagonals. The corresponding process of unloading led to a permanent set and a hysteresis loop representing frictional energy loss in the system. A criterion of failure due to compression along an arbitrary direction in a principal plane was set up on the basis of gross sliding of spheres in the lattice, and the failure stress, dependent on the coefficient of friction and the angle of loading, was determined.

An inherent difficulty appears when such analysis is applied to either of the close-packed arrays. Due to the fact that each of these structures is statically indeterminate, it is necessary to consider, in addition to equations expressing equilibrium of forces and moments, relations insuring compatibility of relative displacements of the constituent spheres. But the latter involve the stiffnesses of the contacts, which depend on the contact forces and, in general, on the loading history; hence, the equations for the determination of the incremental contact forces involve the history of loading.

Accordingly, in the studies of the face-centered cubic array by Duffy and Mindlin (17) and the hexagonal close-packed array by Duffy (18), the authors considered an initial isotropic pressure followed by an arbitrary incremental stress. The contact forces due to the initial loading were now found without difficulty and the change in the stiffnesses arising from the small additional loading was neglected. The incremental stress-strain relations obtained in this manner have the form appropriate, in the case of the face-centered cubic, to a crystal of the cubic system; in the case of the hexagonal close-packing, to a crystal of the hexagonal system.

The incremental form of these stress-strain relations is applicable to problems of small vibrations of the medium under initial isotropic pressure, because then the deviation of the stress and, hence, of the contact forces from their initial values is negligible. The phase velocity of compressional waves in a granular bar was computed for each of the two densest packings (17), (18) and corresponding to several directions of propagation relative to the lattice. Once again the theory predicted the proportionality to the sixth-root of the isotropic pressure which had been the result of previous theories. But the quantitative agreement of the theory containing effects of tangential contact forces with experiments on specially constructed granular bars was very much closer than of a theory based on Hertz contact alone.

Duffy and Mindlin (17) also computed the incremental contact forces and incremental stress-strain relations for the face-centered cubic array under initial isotropic and uniaxial compressive stress. These expressions form the starting point of an investigation by Thurston and Deresiewicz (19) in which interest centered on predicting the behavior of such an array in a static compression test. Since the additional stress was to be of the order of the initial stress, the total, or finite, stress-strain law was needed, and this could be obtained by integrating the incremental law. However, because the expressions for the incremental contact forces involve the stiffnesses and, by virtue of these, the loading history, their integration amounts to the solution of a system of nonlinear integro-differential equations. Consequently, a loading program was sought subject to which the mathematics would become more tractable. The desired loading consisted of an initial isotropic pressure, followed by an additional uniaxial pressure imposed simultaneously with a related additional isotropic pressure. The corresponding total stress-strain relations, nonlinear in form, were subjected to experimental verification and found to agree with measured results. In the course of these experiments it was found that a gross rearrangement, due to a twinning process, took place in the structure whenever, for a given isotropic pressure, a limiting value of uniaxial pressure was exceeded. This phenomenon was deemed to constitute failure of the lattice. A theoretical computation, based on Coulomb's laws of sliding friction, established a linear relation between the stress inducing failure and the initial pressure.

It may be of advantage to terminate the present account of theories of mechanics of granular media by suggesting a few of the unsolved problems which arise as natural extensions of recent work. One such problem is the derivation of total stress-strain relations corresponding to regular, and, in particular, the densest, configurations of like spheres, subjected to arbitrary external loading. Another problem consists of the formulation of incremental stress-strain relations, appropriate to specified loading, and their subsequent integration, for a medium composed of an isotropic mixture of zones of loose and dense packings of like spheres. A more fundamental, but correspondingly more difficult, problem is the analysis of a model containing a random arrangement of like spherical granules, account being taken of all forces at the contacts. Extension of this assignment may be made by postulating successive sets of spheres inserted in the interstices of each preceding set. And possibly the final task of this sequence lies in the establishment of stress-strain relations and criteria of failure for a model composed of a random packing of particles of arbitrary size and shape, these quantities being specified, perhaps, by empirically arrived at distribution functions.

REFERENCES

1 Hara, G., Theorie der akustischen Schwingungsausbreitung in gekörnten Substanzen und experimentelle Untersuchungen an Kohlepulver, *Elektrische Nachrichten-Technik* **12**, 191–200, 1935.

2 Iida, K., Velocity of elastic waves in a granular substance, *Bull. Earthquake Res. Inst. (Tokyo Univ.)* **17**, 783–808, 1939.

3 Iida, K., The velocity of elastic waves in sand, *Bull. Earthquake Res. Inst. (Tokyo Univ.)* **16**, 131–144, 1938.

4 Takahashi, T., and Satô, Y., On the theory of elastic waves in granular substance, *Bull. Earthquake Res. Inst. (Tokyo Univ.)* **27**, 11–16, 1949; ibid., **28**, 37–43, 1950.

5 Gassmann, F., Elastic waves through a packing of spheres, *Geophysics* **16**, 673–685, 1951; ibid., **18**, p. 268, 1953.

6 Hughes, D. S., and Jones, H. J., Variation of elastic moduli of igneous rocks with pressure and temperature, *Bull. Geol. Soc. Amer.* **61**, 843–856, 1950.

7 Hughes, D. S., and Cross, H. J., Elastic wave velocities in rocks at high pressures and temperatures, *Geophysics* **16**, 577–593, 1951.

8 Hughes, D. S., and Kelly, J. L., Variation of elastic wave velocity with saturation in sandstone, *Geophysics* **17**, 739–752, 1952.

9 Matsukawa, E., and Hunter, A. N., The variation of sound velocity with stress in sand, *Proc. Phys. Soc. Lond. (B)* **69**, 847–848; 1956; AMR **10**, Rev. 3107.

10 Brandt, H., A study of the speed of sound in porous granular media, *J. appl. Mech.* **22**, 479–486, 1955; AMR **9**, Rev. 2760.

11 Nasu, N., Studies on the propagation of an artificial earthquake wave through superficial soil or sand layers, and the elasticity of soil and sand (in Japanese), *Bull. Earthquake Res. Inst. (Tokyo Univ.)* **18**, 289–304, 1940.

12 Fatt, I., The effect of overburden pressure on relative permeability, *J. Petroleum Technology*, Tech. Note 194, 15–16, 1953.

13 Fatt, I., Compressibility of a sphere pack—comparison of theory and experiment, *J. appl. Mech.* **24**, 148–149, 1957.

14 Mindlin, R. D., and Deresiewicz, H., Elastic spheres in contact under varying oblique forces, *J. appl. Mech.* **20**, 327–344, 1953; AMR **7**, Rev. 730.

15 Smith, W. O., Foote, P. D., and Busang, P. F., Packing of homogeneous spheres, *Phys. Rev.* **34**, 1271–1274, 1929.

16 Deresiewicz, H., Stress-strain relations for a simple model of a granular medium, ASME Pap. no. 57-A-90, to appear in *J. appl. Mech.*

17 Duffy, J., and Mindlin, R. D., Stress-strain relations and vibrations of a granular medium, *J. appl. Mech.* **24**, 585–593, 1957.

18 Duffy, J., A differential stress-strain relation for the hexagonal close-packed array of elastic spheres, Tech. Rep. no. 3, Office of Naval Research Contract Nonr 562(14) with Brown Univerasity, 1957.

19 Thurston, C. W., and Deresiewicz, H., Analysis of a compression test of a model of a granular medium, Tech. Rep. no. 27, Office of Naval Research Contract Nonr 266(09) with Columbia University, 1958.

Theoretical and Experimental Methods

(See also Revs. 1904, 1905, 1919, 1920, 1923, 1926, 1930, 1931, 1934, 1951, 1978, 1981, 1983, 1997, 2019, 2021, 2028, 2053, 2054, 2071, 2104, 2300, 2301, 2320, 2344, 2350)

Book—1850. Johnson, R. E., and Kiokemeister, F. L., Calculus with analytic geometry, New York, Allyn and Bacon, Inc. (College mathematics series), 1957, xi + 650 pp. $7.95.

Theoretical basis of the calculus and natural geometrical as well as physical applications of methods and results are usefully combined. Enough analytic plane geometry and geometry of solid bodies are included to make it self-contained in this respect. Chapters are as independent of each other as possible, and more difficult theoretical parts are put in separate sections of the numerous sections of each chapter.

Beginning with topics from algebra, introduction to analytic geometry, functions, limits and derivatives, differentiation, applications of derivatives, adhic sections and other algebraic curves, other chapters follow giving definite integral, integral as limit of a sum, differentiation of transcendental functions, elementary and advanced formal integration, and further applications of calculus. Next chapters lead to mean value theorem with related topics, parametric equations and polar coordinates with applications, infinite series and solid analytical geometry. The last 3 of the 20 chapters show partial differentiation, multiple integration and simple differential equations, introducing also the character of its general theory. Most of the sections of each chapter conclude with typical examples which facilitate very much the understanding of the presented theories. Moreover a good choice of exercises allows the reader to become familiar with theories and applications; answers for each exercise are given at the end of the book. A useful table of 85 integrals is added.

Primarily the book has been designed to be used by college students, but it may be also a good guide for engineers to repeat or to learn a theoretical basis of the calculus and of analytical geometry. Thus it may contribute to a larger interest and a deeper understanding of mathematical theories and their applications.

F. Keune, Germany

1851. Roth, J. P., and Scott, D. S., A vector method for solving linear equations and inverting matrices, *J. Math. Phys.* **35,** 3, 312–317, Oct. 1956.

Authors comment that a paper by E. W. Purcell ["The vector method of solving linear equations; AMR **7,** Rev. 2059] does not always work, since division by zero may occur. Present authors remedy this defect. Scheme is advantageous for digital machines since one can rescale at each stage of the process. Thus scheme is less sensitive to round-off errors than other methods. There is a disadvantage since technique requires about $5n^3$ operations to invert a matrix of order n.

Y. L. Luke, USA

1852. Kadoya, M., The extreme-value law and some of its solutions for engineering problems, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 507–509.

Paper treats three types of extreme-value distributions; Gumbel, Type A, and Type B logarithmic. Expressions for mean, mode, median, variance, coefficients of variation, skew, and excedence are given. Method of solution of extreme-value problems is given for each case under certain conditions. A tabular method is used, with a table included. Author believes A-type of logarithmic extreme-value distribution is useful in solution of hydrologic problems. Paper is marred by many grammatical errors inherent in school-boy translation from another language.

T. Hunter, USA

1853. Riftin, L. P., The analytical theory of conoids (in Russian), Thesis, Leningrad Institute of Precision Mechanics and Optics, Leningrad, 1956; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8038D.

Book—1854. Diaz, J. B., and Payne, L. E., editors, Proceedings, Conference on differential equations, Univ. of Maryland, Mar. 17–19, 1955; College Park, Md., University of Maryland Book Store, 1956, xii + 294 pp.

Differential systems with boundary conditions at more than two points, Whyburn, W. M.:

Paper considers ordinary differential systems of the form

$$y_i' = f_i(x, y_1, y_2, \ldots, y_n), \qquad (i = 1, 2, \ldots, n)$$

in the real domain, with boundary conditions involving more than two points of an interval $a \leqslant x \leqslant b$. Boundary conditions involving "initial" values at more than one point are treated in some detail; brief references are made to conditions which involve more than the two end-points a and b, and to conditions which involve the end-point a and b, and to certain conditions at interior points.

Sturm-Liouville and heat equations whose eigenfunctions are ultra-spherical polynomials or associated Bessel functions, Bochner, S.: Solutions of the two equations

$$(1 - x^2)f_{xx} - (2\gamma + 1)x f_x = f_t, \qquad -1 \leqslant x \leqslant 1$$

$$f_{xx} + (2\gamma/x)f_x = f_t, \qquad 0 \leqslant x \leqslant \infty$$

are studied for arbitrary real γ.

Repeated branching through loss of stability, an example, Hopf, E.: Following up his earlier paper on a mathematical example displaying features of turbulence [AMR **2,** Rev. 358], author treats an example of an integro-differential equation in two dependent and two independent variables (x, t) whose limiting solutions as $t \to \infty$ become more and more complicated in a discontinuous manner as a certain parameter decreases to zero through an infinite number of critical values.

Problems related to characteristic surfaces, Riesz, M.: The solution of the wave equation for characteristic boundaries is studied by the author's method of analytical continuation of Riemann-Liouville integrals. Characteristic surfaces in m dimensions intersect themselves in $(m-2)$-dimensional varieties called keels, and the solutions lead to interesting formulas of "curvatura integra" and sequences of special functions which are related to given characteristic surfaces in the way that different powers of the Lorentz distance are related to characteristic cones.

On the Euler-Poisson-Darboux equation, integral operators, and the method of descent, Diaz, J. B. and Ludford, G. S. S.: Paper commences with a self-contained account of the solution of Cauchy's problem for

$$\Delta u = u_{tt} + (k/t)u_t,$$

but for $-\infty < t < \infty$, instead of $t \geqslant 0$ as usual. A second section is devoted to the generation of solutions of linear hyperbolic equations in two independent variables by combining the ideas of LeRoux and Bergman, and a third section shows how a reflection principle may be used to continue analytic solutions of elliptic equations.

On partial differential equations of mixed type, Protter, M. H.: After an extensive and valuable discussion of previous work on equations of mixed type, author proves existence and uniqueness theorems for the equation

$$K(y)b(x, y)u_{xx} - u_{yy} + a(x, y)u_x + b(x, y)u_y + c(x, y)u + f(x, y) = 0,$$

where $K(y)$ is monotone increasing with y, $K(0) = 0$, and $b(x, y) > 0$, for boundary values of u given on a segment of the x-axis and a characteristic curve through one of its end-points.

Some applications of Riesz's method, Copson, E. T.: Direct application of Riesz's method of analytical continuation is made to mixed initial-value problem for the three-dimensional wave equation arising from Burger's treatment [Nat. Aero. Res. Inst., Amsterdam, Rep. F. 157, 1954] of the half-plane diffraction problem, and to Cauchy's problem for the equation of damped waves, where

it is shown that it is unnecessary to use Fremberg's kernal involving a Bessel function.

Discontinuity and representations of minimal surfaces, Chen, Y. W.: It is shown that the solutions of the equation for minimal surfaces when the boundary curves have points of tangential discontinuity behave differently from conformal mappings, and, due to the nonlinearity, may not even exist. How to modify the boundary conditions so that solutions exist is an important consideration in the hodograph method for compressible-flow problems.

Relations between different capacity concepts, Szegö, G.: If C is the Newtonian capacity, and c is the logarithmic capacity of a closed domain D, then it is shown that

$$\pi C/2c \leqslant 1.07.$$

The previous best value for the constant on the right is 1.12.

Some results on generalized axially symmetric potentials, Huber, A.: Paper gives some results concerning existence and nonexistence of solutions to problems of Dirichlet's type for the equation

$$\Delta u + (k/x_n)u_{x_n} = 0,$$

some mean-value properties of the solutions, and some integral representation theorems. The last hold only for integer values of k, but the other results are established for nonintegral values.

On the numerical solution of the Dirichlet problem, Nehari, Z.: It is shown that some difficulties associated with the usual solution of Dirichlet's problem for Laplace's equation by series of orthonormal harmonic functions can be removed if the Dirichlet norm is replaced by suitable boundary norms. An alternative modification is to replace the set of harmonic functions by sets of functions which are not harmonic, but which have the correct boundary values. It is shown further that similar methods can be used to solve Dirichlet's problem for the equation

$$u_{xx} + u_{yy} = P(x, y)u,$$

where $P(x, y)$ is positive and continuous.

Bounded or almost-periodic solutions of nonlinear differential systems, Amerio, L.: Nonlinear equations of the form

$$X' = F(t, X) \qquad [1]$$

are considered, where $X(t) = \{x_1(t), \ldots, x_n(t)\}$ is an unknown vector, and t is the independent variable. For suitable conditions on F, these equations possess an almost-periodic solution. The results are applied to the system of equations

$$X'' = -MX - \Phi(X') + F(t) \qquad [2]$$

which describe the motion of a point mass under the action of a linear elastic force $-MX$ with M constant and positive definite, a dissipative force $\Phi(X')$ (for sufficiently large $|X|$), and a continuous and bounded force $F(t)$. Then [2] possesses at least one bounded solution, and, if $F(t)$ is periodic, there is a periodic solution. Under more restrictive conditions on Φ, it is shown that the bounded solution is unique, that every other solution converges to this solution as $t \to \infty$, and that the bounded solution is almost-periodic if $F(t)$ is almost-periodic.

The extension of the Riemann mapping theorem to elliptic equations, Dressel, F. G., and Gergen, J. J.: Paper discusses past and recent results concerning the existence and uniqueness of pairs of mapping functions $u(x, y)$, $v(x, y)$ which give a 1:1 mapping of a Jordan domain D in the (x, y)-plane onto a Jordan domain Δ in the (u, v)-plane, and which satisfy linear elliptic equations of the form

$$au_x + bu_y = v_y, \quad cu_x + du_y = -v_x.$$

On the eigenfunctions of the membrane equation in a singular case, Pleijel, A.: The asymptotic behavior of the eigenfunctions of the equation

$$\Delta u + \lambda k(x, y, z)u = 0, \quad k(x, y, z) \geqslant 0,$$

which vanish on the boundary S of a finite domain V of (x, y, z)-space is studied for a subdomain V_0, with boundary S_0, in which k vanishes. If $\lambda_1 \leqslant \lambda_2 \leqslant \lambda_3$, etc., are the eigenvalues, and the corresponding eigenfunctions are ϕ_1, ϕ_2, ϕ_3, etc., orthonormalized so that

$$\int_V k\,\phi_m\,\phi_n\,dV = \delta_{mn},$$

then the principal result of the paper is that the series

$$\sum_{n=1}^{\infty} \phi_n^2(p)/\lambda_n$$

converges if $p \in V_0$, although it diverges if $p \in (V - V_0 - S_0)$; other series connected with Green's functions are also investigated.

An abstract formulation of the method of separation of variables, Friedman, B.: The method of separation of variables for partial differential equations is formulated in terms of direct products of Hilbert spaces. By this formulation we can determine the possible boundary conditions for which the method is applicable. Finally, a contour representation is given for the solution of some partial differential equations. (Author's abstract)

The heat equation and the Weierstrass transform, Widder, D. V.: Paper discusses the problems of inversion and representation when transformed function is bounded, in which case some technical difficulties of the general case are absent; the general case is treated in Hirschman and Widder's book, "The convolution transform."

Extensions of operational mathematics, Churchill, R. V.: If a function $F(x)$ satisfies a linear differential equation and prescribed boundary conditions at the ends of the interval (a, b), then suitable choice of the kernal K and the domain of s in the linear integral transformation

$$f(s) = \int_a^b K(x, s)\,F(x)\,dx$$

may lead to a simpler problem for $f(s)$, and properties of such transformations can be used to obtain properties of the solutions to such boundary-value problems as well as the solutions themselves. Primary purpose of paper is to determine the transformation when the differential equation and the boundary conditions are prescribed. Some special cases are considered.

On general Sturm-Liouville operators, Feller, W.: The general form of linear differential operators of the second order which have certain specified local properties is derived, and some results on their semi-boundedness in Hilbert space, minimal solutions, behavior at boundaries, and Green's functions are obtained.

Heat transfer to Hagen-Poiseuille flows, Millsaps, K., and Pohlhausen, K.: The problem considered is the determination of the thermal profiles when a viscous liquid in laminar motion is flowing in a circular cylindrical tube, and the wall of the tube and the liquid are maintained at constant temperature up to a certain cross section at which the wall temperature is changed to a new value for the remainder of the tube. Original treatments by Nusselt and Graetz neglected dissipation due to viscosity and axial curvature of the thermal profiles, which are included in the present treatment since their effects are not negligible for liquids with small Prandtl numbers (such as liquid metals used in nuclear reactors). It is assumed that the physical properties of the liquids are constants, so the results hold only for small temperature changes. The resulting equation for the temperature leads to an eigenvalue problem, and extensive numerical and graphical results are given.

G. N. Ward, England

1855. Bakhvalov, N. S., Convergence conditions and the order of errors in solving the Cauchy problem for one linear equation of the first order by the method of finite differences (in Russian), *Prikl. Mat. Mekh.* **20**, 2, 279–283, Mar.–Apr. 1956.

Author considers numerical solution of the partial differential equation: $u_t + a(t, x)u_x - b(t, x)u = 0$, by the method of finite differences with the initial condition $u(0, x) = u_0(x)$, and assuming that $a(t, x) \geqslant 0$.

In case of forward differences it is well known that the solution of the difference equation converges to the solution of the differential equation when the coefficient functions a and b are differentiable. Author proves the above-mentioned convergence in cases when the coefficient functions a and b satisfy a number of conditions but are not necessarily differentiable.

T. Leser, USA

1856. Bertram, G., Estimation of error for the second boundary-value problem of plane potential theory (in German), *ZAMM* **36,** 1/2, 1–35, 1956.

An estimate of the error of the approximate solution of the Neumann problem for the Laplace equation in the plane is obtained for a simply connected region by conformally mapping the region on the interior of a circle. The class of approximations consists of functions which are harmonic on the interior of the region. Two estimates are given in terms of the difference between the normal derivative of the approximate solution and the given normal derivative on the boundary and the modulus of the function which maps the given region on the interior of the unit circle. One of these estimates is evaluated for the cases of a circle, a semi-circle, a rectangle, and a square. The method is also extended to the three-dimensional spherical region. C. Saltzer, USA

1857. Suray, S., On the analytic functions of order $n - 1$ (application to the plane elasticity), *Quart. appl. Math.* **15,** 3, 283–290, Oct. 1957.

Analytic functions of order n, introduced by P. Burgatti, are expressions of the form

$$\Omega(z, \bar{z}) = \sum_{\nu=0}^{n-1} \bar{z}^{\nu} f_{\nu}(z)$$

where $f_{\nu}(z)$ $(\nu = 0, 1, \ldots, n-1)$ are arbitrary analytic functions of the complex variable $z = x + iy$ in a domain D and $\bar{z}$ is the imaginary conjugate of z.

Author points out that properties of these functions are closely related to those of polyharmonic functions of two variables. Several theorems regarding transformations applied to analytic functions of order n are proven and are used to derive some of the properties of the stress deviator of a two-dimensional elastic field when its argument undergoes the transformation $(az + b)/(cz + d)$, where a, b, c, and d are arbitrary complex constants.

J. W. Clark, USA

1858. Arbenz, K., Integral equations for some boundary-value problems for domains with sharp corners (in German), *ZAMP* **8,** 3, 251–254, Mar. 1957.

The boundary-value problems discussed are: to determine (*) a conformal mapping of a region with corners into a circle; (**) the Airy function for a plane thin plate with corners, boundary forces lying in the plane. Numerical usefulness of the methods is essential.

As to the method, the reader should consult, e.g., literature given in Warschawski, "On the effective determination of conformal maps," *Ann. Math. Stud.* no 30, Princeton 1953. In the present paper, integral equations for boundary functions, generating the mapping function and the Airy function, are given. Unique solubility and other general results are stated without proof in case (*). Author makes the numerical usefulness probable by means of an example.

The general approach is not new. In case (*), regions without corners have been treated even numerically by means of essentially the same integral equation as the author's [see op. cit.]. The contribution of the present paper seems to be the announced extension of numerical treatment to cases (*) and (**), which are of great importance. Estimates of errors are missing.

G. Borg, Sweden

1859. Nazarov, O. O., Solution of the differential equations of equilibrium of a slanting covering with a given rectangular surface by the method of simple trigonometrical series (in Russian), *Dop. Akad. Nauk URSR* no. 1, 13–19, 1956; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8462.

The equation of equilibrium of a slanting covering, rectangular in plan, is solved in the form

$$\Phi(x_1 x_2) = \sum_{k=1}^{\infty} \Phi_k(x_1) \sin \frac{k\pi x_2}{b}$$

where $\Phi_k(x_1)$ are hyperbolic-trigonometrical functions. This type of solution is analogous to M. Levi's solution concerning the bending of thin plates. Tables are given of numerical calculations of bending and stresses for certain particular cases.

P. M. Varvak

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Book—1860. McCracken, D. D., Digital computer programming, New York, John Wiley & Sons, Inc. (General electric series), 1957, vii + 253 pp.

This is the first comprehensive textbook treatment of programming principles for modern stored-program calculators. Basic techniques are expounded in terms of author's mythical computer TYDAC. Extension to specific digital machines is indicated. Text is self-contained, individual chapters being briefly assessed in relation to the whole.

Fundamentals of coding, systems of numerical representation, principles of scaling, looping, flow-charting and indexing are separately treated. So also are subroutines, input-output, use of auxiliary storage, and methods of relative and interpretive programming. The book ends with a brief outline of automatic coding developments. Adequate examples are worked in the text and suggested exercises terminate most chapters.

Reviewer feels that book provides a good approach for newcomers to the field. It summarizes ideas which have become widespread in the past ten years. There is no claim to originality, since programming principles were first detailed by Lady Lovelace [Bowden, B. V., "Faster than thought," Sir Isaac Pitman & Sons, Ltd. London, 1953] and have been independently developed in manuals of operation for numerous recent machines. Also applications of computers have more adequately been treated elsewhere [e.g. Canning, AMR **10,**(1957), Rev. 619]. TYDAC, with its 73 single-address instructions and extensive auxiliary equipment, is unnecessarily complicated to warrant study by the single-shot user of a specific machine. However, its concept is clear, and it well illustrates the many aspects to be understood by a professional programmer of a real machine.

Beatrice Worsley, Canada

Book—1861. Eckert, W. J., and Jones, Rebecca, Faster, Faster, New York, McGraw-Hill Book Co., Inc., 1955, vii + 160 pp. $3.75.

This book discusses a particular electronic calculator, the IBM Naval Ordnance Research Calculator (NORC). The authors have adhered to a nontechnical vocabulary quite successfully and have written a relaxed exposition covering some principles of electronic performance, some parts of the operation, and some problems solved by this calculator.

As a primer on the NORC the book is slightly marred by the usual obsession with the exact number of microseconds per opera-

tion. The manufacturer, who holds the copyright on this publication, is mentioned rather frequently.

E. J. McBride, USA

1862. Vannah, W. E., Improved performance: the computing-control goal, *Control Engng.* **4,** 9, 126–128, Sept. 1957.

1863. Imsland, T. S., and Hornfeck, A. J., Continuous monitoring equipment for power plant cycles, ASME Ann. Meet. New York, N. Y., Dec. 1957, Pap. 57-A-176, 12 pp.

Equipment has been developed to monitor continuously on a real time basis by feeding information in the form of measured data of a power-plant cycle directly into an analog computer. Computed outputs such as boiler efficiency, turbine-cycle heat rate and over-all cycle heat rate are indicated and recorded continuously and in some instances may be converted into digital form.

From authors' summary by J. H. Kennan, USA

Book—1864. Goode, H. H., and Machol, R. E., System engineering, New York, McGraw-Hill Book Co., Inc., 1957, xii + 551 pp. $10.

This book has two ambitious purposes. First it attempts to weld together the many things that make up the new discipline of system design: "a new set of tools, a new classification of parts, an organized approach and a team of workers." Secondly, it aims "to provide for the engineer who is or aspires to be a member of a system-design team sufficient technical background to aid him in his job." On the whole the authors achieve their second purpose better than the first.

At the outset it is agreed that systems design, systems analysis, or the systems approach means many things to many people. It is not, however, immediately evident what it means to the authors. They say system design deals with complex large-scale systems and it requires an integrated team approach, but, for example, such problems as putting together an optimum nuclear power system or designing an automatically controlled refinery do not seem to belong in their frame of reference. Examples of what they consider to involve system design are: control of traffic lights in a city, aircraft blind landing systems, automatic reservation systems for airlines or trains, telephone switching systems, direct distance dialing systems, automatic electronic component assembly, inventory problems for the armed services and large industries, post-office systems, the continental air-defense systems, etc. It appears that a common denominator in all these is the occurrence of non-deterministic aspects which require probabilistic considerations. Many of these problems have been considered as lying in the domain of *operations research.* For some reason the authors appear prejudiced against this designation. There are only two pages devoted to operations research. Here it is grudgingly admitted that "there has been a recent tendency to broaden the definition of operations research, so that it is practically synonomous with system design." In their view, the difference is "The operations analyst is primarily interested in making procedural changes, while the systems engineer is primarily interested in making equipment changes."

A member of a system-team must be not a specialist but a scientific *generalist.* To educate this generalist there are introductory treatments of a wide variety of special fields. These are quite good. They are interesting and lively and, on the whole, do give sufficient information "to allow intelligent decision on whether, for his problem, the reader needs an expert in the field or must delve more deeply into the field himself." The fields discussed include probability theory, statistics, design of experiments, analog and digital computers, queuing theory, game theory, linear programming, group dynamics, cybernetics, simulation, information theory, servomechanism theory, human engineering, economics and management.

While the individual topics are well introduced, the attempt to weld them into a unified picture of system design is less successful. There are several flow diagrams and listings of procedural steps in general terms and there are some detailed discussions of isolated phases of particular problems but the over-all picture remains cloudy. The only extended example is provided by representing a paper by W. D. Turner which was presented at the Operations Research Conference at Case Institute in 1953. This deals with what the authors call the exterior design problem, namely the formulation of a particular problem in terms of "the requirements on the system and its environment." It is too bad that it was not possible to follow up this example with a discussion of the *interior* design problem, namely "the design choices relative to equipment, procedures, and people, i.e., the system itself."

An attempt to give the over-all picture is made in chap. 3 in terms of a chronological description of the functioning of a system design team. At this stage of the book the reader has not been able to absorb the full significance of the specialized terminology (e.g., exterior and interior design, single thread design, high-traffic design, competitive design) which is developed in the succeeding chapters, if indeed he has a clear notion of the text usage of system-design itself. If this chapter had come later and if it had followed through a specific example from beginning to end, it would have done much to pull the book together.

S. H. Crandall, USA

Book—1865. Topping, J., Errors of observation and their treatment, London, Institute of Physics, 1955, 119 pp. 5s. (paper-bound).

1866. Kuhn, H. W., A note on Prager's transportation problem, *J. Math. Phys.* **36,** 2, 107–111, July 1957.

In his paper "A generalization of Hitchcock's transportation problem," title source **36,** 99–106, 1957, Prager approaches the problem by analogy with mechanics of continua. Kuhn presents the problem from the viewpoint of linear programming. The results in the two papers are identical, but Kuhn, conceding the ingenuity and elegance of Prager's treatment and its naturalness for those trained in continua theory, presents a discussion to show the advantages of the linear programming approach. These are: (1) The concepts introduced are more appropriate to the intended theory and applications; (2) the theorems of linear programming theory, in particular duality theory, may be brought to bear, resulting in a mathematically more complete theory.

H. D. Block, USA

1867. Saaty, T. L., Resume of useful formulae in queuing theory, *J. Operat. Res. Soc. Amer.* **5,** 2, 161–200, Apr. 1957.

1868. Luchak, G., The distribution of the time required to reduce to some preassigned level a single-channel queue characterized by a time-dependent Poisson-distributed arrival rate and a general class of holding times, *Operat. Res.* **5,** 2, 205–209, Apr. 1957.

Book—1869. Beyer, R. T., and Williams, A. O., Jr., College Physics, New York, Prentice-Hall, 1957, xi + 660 pp. $7.50.

This book, intended for a one-year liberal arts course in general physics, is interestingly written, with good illustrations and exercises. Historical and philosophical attitudes are emphasized throughout. The authors must be commended for their refreshing attitude of being willing to give semi-quantitative discussion of almost any topic in modern physics.

The first two chapters are largely historical and philosophical, and might be read to better advantage at the end of the course, after the student has come to understand the terms used. Chapter 3, which begins the technical work, is concerned with kinematics; this is followed by chap. 4 on laws of dynamics, and chap. 5 on

momentum and energy. Not until chap. 8 (which follows discussions of elasticity, dynamics of rigid bodies) is statics discussed. Although this may have some philosophical advantage, the beginning student will probably not find this sequence as clear physically as in the case of the more conventional sequence which first treats statics and then dynamics. One consequence of the present treatment is that force is defined (p. 58) as the product of mass and acceleration.

There is a tendency to include fairly advanced ideas in the initial discussion of topics; for example, the discussion of momentum and energy begins on page 72, and by page 76, the formula for the relativistic change in mass is presented. Reviewer feels it would be preferable to complete the discussion of classical physics before indicating ways in which classical theories have been modified; not to do so may prevent the student from attaining a firm and confident grasp of basic ideas.

The book probably explores some topics somewhat further than is appropriate for its stated purpose (e.g., discussion of equivalent circuit for triode amplifier, p. 487), but on the whole a wealth of useful material is made available to the student. Chapters on heat, fluids, acoustics, kinetic theory, thermodynamics, light waves, optics, electrostatics, electric circuits, magnetism, generators and motors, electronics, radiation, atomic theory, spectroscopy, nuclear physics, and astrophysics are included. There are several pages of well-chosen problems at the end of each chapter. (Reviewer would, however, object to a few problems, such as "Compute the internal energy of 2 moles of oxygen at 0 C, neglecting the constant," on p. 281.)

Calculus is not explicitly used, and a review of trigonometry is given in an appendix which includes tables of natural trigonometric functions.

An interesting innovation is that the final chapter describes the place of the physicist in modern society—including organizations, places of employment, role in technology, postwar shortages, economic factors, and security regulations. Reviewer would tend to differ with the implication on page 631 that scientists are not equipped to discuss problems in such fields as politics and religion; one result of a scientist's training is, for example, a willingness to question authority, and this is an attitude which can contribute in a number of fields other than science.

C. E. Pearson, USA

The following papers appeared as part of the "Symposium on high pressure," *Indust. Engng. Chem.* **49**, 12, Dec. 1957.

1870. Vernon, L. M., and Sliepcevich, C. M., Heat transfer in a high pressure reactor, 1945–1948.

A practical design eliminates need for internal cooling or heating coils or external jacketing. From authors' summary

1871. Newhall, D. H., Hydraulically driven pumps, 1949–1954.

The future need for higher pressure with consequent demand on equipment will make these pumps increasingly important.

From author's summary

1872. Bleyle, G. A., Jr., Crosby, H. W., and Kendall, R. E., Liquid nitrogen pump and vaporizer, 1955–1958.

Through the use of this pump, a packing consisting of graphitized shredded Teflon interspaced with Teflon washers has been developed. The results of this development have been applied to a pump of much larger capacity, which has sucessfully passed preliminary tests. From authors' summary

1873. Frederick, D. D., and Porter, R. L., A high pressure air-driven pump, 1959–1961.

This design method produced a successful pump made to operate at 60,000 pounds per square inch.

From authors' summary

1874. Wolf, R. C., and Bowen, J. C., Compressing of gases in the pure state to high pressures, 1962–1964.

The diaphragm compressor provides pure gas at pressures up to 2000 atm for research and pilot-plant requirements. It is especially valuable in handling toxic, explosive, flammable, or expensive gases. From authors' summary

1875. Birch, F., Robertson, E. C., and Clark, S. P., Jr., Apparatus for pressures of 27,000 bars and temperatures of 14,000°C, 1965–1966.

Temperature, pressure, and other variables may be controlled and measured in the reaction zone with unusually high precision.

From authors' summary

1876. Shepard, B. M., Hypervelocity missile launcher, 1967–1968.

Launcher built to test model rockets may be a practical high-temperature pressure vessel for chemical processes.

From author's summary

1877. Manning, W. R. D., Strength of cylinders, 1969–1978.

New design methods are described here for meeting problems of fatigue and creep imposed by higher temperatures and fluctuating loads. From author's summary

1878. Faupel, J. H., and Harris, D. B., Stress concentration in heavy-walled cylindrical pressure vessels; effect of elliptic and circular side holes, 1979–1986.

Experimental as well as theoretical information is given in a field where most designers have had to make hopeful guesses.

From authors' summary

1879. Price, D., and Lalos, G. T., Adiabatic compressor for P-V-T measurements on gases to 100,000 pounds per square inch, 1987–1992.

After calibration with carbon dioxide to 20,000 pounds per square inch, P-V data on nitrogen could be obtained to about 25,000 per square inch. From authors' summary

1880. Newhall, D. H., A new high pressure technique; the controlled-clearance principle, 1993–1995.

This promising technique has been successful in studying rock deformation under pressure; measuring extreme pressures; stirred autoclaves. From author's summary

1881. Ellison, R. W., Very fast flow control techniques, 1996–1998.

High-speed controls for high pressure systems, resulting from work on rockets and jet engines, can be applied in the chemical industry. From author's summary

1882. Ross, J. F., and Brown, G. M., Viscosities of gases at high pressures, 2026–2033.

The viscosities of methane, nitrogen, and helium have been determined in a new type of viscometer using instrument bellows and a capillary tube in the range 25° to 50° and 500 to 10,000 pounds per square inch gage.

From authors' summary

1883. Luft, L., Constant pressure method for determining P-V-T relations of gases, 2035–2039.

A basically new method promises to fill a need coming from the trend to processes operating at high temperatures and pressures.

From author's summary

1884. Johannin, P., and Vodar, B., Thermal conductivity of nitrogen at high temperatures and pressures, 2040–2041.

1885. Long, D. E., and Comings, E. W., Thermal conductivity of propane, 2042–2045.

New experimental measurements show behavior which differs considerably from that previously measured, and indicate how methods of prediction now in the literature may be corrected.

From authors' summary

1886. Johnson, D. P., Cross, J. L., Hill, J. D., and Bowman, H. A., Elastic distortion error in the dead-weight piston gage, 2046–2050.

Development of the intermolecular theory depends on high accuracy pressure-volume-temperature measurements which in turn depend on understanding limitations of the piston gage. Error growth from data uncorrected for gage distortion is shown here.

From authors' summary

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 1944, 1950, 1959, 1985, 2039, 2059, 2395)

1887. Lawden, D. F., Optimal rocket trajectories, *Jet Propulsion* **27,** 12, p. 1263, Dec. 1957.

1888. Leitmann, G., On the equation of rocket motion, *J. Brit. interplanetary Soc.* **16,** 3, 141–147, July-Sept. 1957.

1889. Lawden, D. F., and Fellow, M. A., The simulation of gravity, *J. Brit. interplanetary Soc.* **16,** 3, 138–140, July-Sept. 1957.

The artificial gravitational field produced by rotating a spaceship or artificial satellite about its axis is compared and contrasted with normal gravity at the earth's surface.

From authors' summary

1890. Hughes, G. W., The trifilar pendulum and its application to the experimental determination of moments of inertia, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-51, 16 pp.

A trifilar pendulum consisting of a platform suspended by three wires may be used to determine the moment of inertia of an object by measuring the period of oscillation of the platform when the object is placed upon it. This paper describes the pendulum and derives the equation for the vibrating system. Accuracies obtainable are discussed, together with various features of operation, including an electric timer which has been developed for use with the pendulum.

From author's summary

1891. Boydalov, A. K., Graphical methods for the solution of fundamental problems in three-dimensional statics (in Russian), *Uch. zap. Yaroslavsk. tekhnol. in-ta* **1,** 215–226, 1956; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8033.

1892. Lifschitz, Ya. D., A new method for the resolution of force in six directions (in Russian), *Trudi Kievsk. avtomob. dor. in-ta* no. 1, 120–127, 1953; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8031.

1893. Steeds, W., Ellis, J. R., and Thomson, J. L., Transmission wind-up in vehicles having several driven wheels, Instn. mech. Engrs. Auto. Div., Prepr., 14 pp. + 6 figs., Apr. 1956.

By wind-up is meant the twist that occurs in the transmission of a vehicle having several driven wheels but which is not provided with sufficient differentials to insure equal distribution of the driving torque between the wheels, and which is due to inequalities in the effective rolling radii of the wheels. The first part of the paper discusses the importance of the wind-up phenomena and describes some experiments made on a rig in which wind-up could be developed and the wind-up torque be measured. The results show clearly that wind-up quickly reaches a steady state and that during this phase the effective rolling radii of the wheels change until they become equal.

The second part of the paper describes some experiments, made on another rig, in which the effects of speed of rotation, radial load, inflation pressure, and torque transmitted on the effective rolling radius of a pneumatic tire could be determined.

A selection of the results obtained is given in a series of graphs. The most important result is the establishment of the fact that the effective rolling radius of a tire is a function of the torque transmitted by it and that if this function is known then the wind-up torque can be calculated. Paper concludes with a summary of the results obtained and some suggestions for ameliorating the harmful effects of wind-up.

From authors' summary

1894. Geronimus, Ya. L., Some properties of motion under the action of central force (in Russian), *Trudi Khar'kovsk. aviats. in-ta* no. 15, 17–20, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6382.

Author notes a number of properties of plane motion of a material point under the action of a central force and determines a transformation transferring the trajectory of the point to the hodograph of its velocity. This result is generalized for the case of any plane curve and any given surface. A formula expressing the central force by a radius-vector is derived and a method of graphical construction of the trajectory with a given central force is examined.

V. V. Dobronravov

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1895. Zunnunov, N. Z., General equations of the dynamics of bodies of varying mass (in Russian), *Trudi Sredneaz. in-ta* no. 37, 35–41, 1954; *Ref. Zh. Mekh.* no. 10, 1956; Rev. 6384.

Author examines the motion of a system of points of varying masses having holonomial ideal links. Equations are derived for the motion of a system in vector form and in generalised coordinates.

M. I. Efimov

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1896. Zil'berman, Y. S., Theorem of the kinematics of plane motion (in Russian), *Trudi Rostevsk. in-ta inzh. zh-d. transp.* no. 19, 179–199, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6459.

Introducing the concept of linear acceleration of a point as the relationship of the vector of the acceleration of this point to the square of the angular speed of the plane figure, author demonstrates the theorem: the section of a straight line connecting the ends of the linear accelerations of two points of a plane figure is perpendicular to a straight line passing through these two points.

It is shown how, on the basis of this theorem, it is possible to determine the accelerations of points, the instantaneous centers of accelerations, and the turning circles of elements of mechanisms without having to construct planes of velocities and accelerations.

An application of the theorem to the kinematic analysis of a cranked, four-member planetary mechanism is given, as well as to the investigation of the rolling of the figure according to an immobile curve.

N. V. Butenin

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1897. Popov, Yu. N., The problem of the impact of a ship on an ice floe (in Russian), *Trudi Leningr. Korablestroit. in-ta* no. 15, 42–52, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7595.

The equations of the impact (collision) between two bodies are given in their known form as follows

$$M_i \Delta v_i = s_i,\ I_i \Delta\omega_i = r_i \times s_i;\ (i = 1,2) \qquad [1]$$

In which M_i = mass of the body; I_i moment of inertia; Δv_i, $\Delta \omega_i$ increment of velocity of the center of gravity and the angular velocity; S_i impact momentum. The system [1] is associated with the equation

$$v_{1n} - v_{2n} = -\epsilon(v_{01n} - v_{02n}) \qquad [2]$$

in which ϵ = coefficient of restitution, v_{01n}, v_{02n}, v_{1n}, v_{2n} are normal components of the velocities of the impact points, before and after the collision. On the basis of Eqs. [1] and [2], different cases of the collision of a ship and an idealized ice floe in the form of a thin circular disk are studied. A number of calculation formulas are set up, and the nondimensional value of the impact momentum $S_0 = S/[M_1(1+\epsilon)v_0]$ calculated in relation to M_1/M_2, where M_1 = mass of ship, M_2 mass of floe, for varying relationships between the structural parameters of the ship and different collision cases. N. N. Moiseev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1898. Dunk, A. C., and Hall, A. S., Jr., Resistance to rolling and sliding, ASME Semiann. Meet., San Francisco, Calif., June 1957. Pap. 57-SA-9, 5 pp.

In general, a single "coefficient of friction" is inadequate to define the frictional resistance between contacting bodies. It is necessary to know both the inclination of the resultant force line and the offset of this line from the theoretical point of contact. This paper presents results of experiments which were made to determine the effects of velocity on the inclination, and the offset of the line of action of the resultant force between two disks in peripheral contact.

The results indicate that the sliding velocity is of primary importance in determining the inclination of the line of action of the resultant force. It is the sum of the sweep velocities that is of primary importance in determining the offset of the resultant force line. The nature of the relationship between the angle of inclination and the offset of the line of action of the resultant force, and the proximity of the contact conditions to those existing for pure rolling, was investigated, but no conclusive results were obtained. From authors' summary

1899. Hain, K., Freudenstein, F., Kiper, G., Rofner, W., Rosenauer, N., Hagedorn, L., Beyer, R., Schnarbach, K., and Volmer, J., Generation of nonuniform rotational motions, *VDI Forschungsheft* **23,** 461, 56 pp., 1957.

Geometrical and analytical methods are thoroughly investigated in this extended survey related to the various engineering designs for the generation of nonuniform rotational motions. The major part of this investigation is devoted to the quadric chain mechanism and its maximum and minimum transmission ratios. Other mechanisms dealt with in detail are: spatial genevas, six-link mechanisms, the turning-block linkage, cams, rope mechanisms, toothed gears with noncircular pitch profiles, and link mechanisms used in conjunction with spur gears. From authors' summary

1900. Zingerman, Yu. M., Graphical solution of problems of three-dimensional kinematics by the projection method (in Russian), Thesis, Moscow Institute of Machine Tools, Moscow, 1956; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8037.

1901. Khromeyenkov, M. F., Dry sliding friction (in Russian), "Mekhanika", (MVTU **50**), Oborongiz, 1956, 272-299; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8030.

Friction in the brakes of motor vehicles is discussed. A theoretical analysis is made of the relationship between brake heating and the braking parameters. G. D. Lomakin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1902. Dobronravov, V. V., The fundamental proposition of the mechanics of nonholonomial systems (in Russian), "Mechanics" (MVTU **50**), Moscow, Oborongiz, 1956, 50-74; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8014.

The three problems are indicated which arise in the analysis of systems with linear, nonholonomic linkages. The first of these problems relates to the derivation of the equations of motion, which can be divided into two groups: in the first (Appel, Volterra), the equations of the nonholonomic linkages are applied in the initial stage of the derivation of the equations of motion; while in the second group (Chaplygin, Hamel), the equations of the nonholonomic linkages are taken into account in the equations of motion finally obtained. The differences in the setting-up of the equations are illustrated on the example of a mechanical system with the determining coordinates q_1, q_2, q_3, which are governed by the equation of nonholonomic linkage:

$$\dot{q}_1 = q_2 \dot{q}_3$$

Appel and Chaplygin equations are set up, as well as equations with indeterminate multipliers.

The equations obtained differ in form, but can be reciprocally transformed by the equation of the linkages.

The second problem consists in the generalization for the case of linear, nonholonomial linkages, of the fundamental theorems of analytical mechanics; the theory of the canonical equations, the theorems of Hamilton and Jacobi, Poisson, and others. In the author's opinion, the important part is played here by the nonholonomial, or quasi-coordinates. The equations of Hamel and Volterra, in quasi-coordinates, are discussed. Disagreeing with the critics [Yu. I. Neumark, N. A. Fuffayev, *Prikl. Mat. Mekh.* **5**, no. 5, 1951] the author defends the correctness of the results of his researches on the mechanics of nonholonomial systems [cf. *Ucb. zap. Mosk. un-ta*, 1948, no. 122, Mechanics, Vol. 2).

The third problem is closely associated with the second and concerns the applicability to nonholonomial systems of the interchangeability of the variations and differentials of the Cartesian and Lagrange coordinates. V. S. Novoselov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1903. Sibirsky, K. S., The principle of symmetry and the problem of the center (in Russian), *Ucb. zap. Kishinevsk. in-ta* **17,** 27-34, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7188.

An equation is examined of the form:

$$dy/dx = -Y(x,y)/X(x,y) \qquad [1]$$

in which $X(x,y)$ and $Y(x,y)$ are functions, analytical in the vicinity of the coordinate origin, the series expansion of which commences with terms not below the first order. It is assumed that the characteristic equation

$$Q_n(\cos\varphi, \sin\varphi)\cos\varphi + P_n(\cos\varphi, \sin\varphi)\sin\varphi\ 0 \qquad [2]$$

has no real roots.

The following proposition is proved:
In order that the field of the linear elements of Eq. [1] shall be symmetrical with respect to the straight line

$$x\sin\varphi \quad y\cos\varphi \quad 0 \quad 0 \quad \varphi \qquad [3]$$

it is necessary and sufficient (and for the presence of a center in Eq. [1], sufficient) that the following identity shall be fulfilled

$$X_1^{(1)}(x_1,y_1,\varphi)Y_1^{(1)}(x_1,y_1,\varphi) = X_2^{(1)}(x_1,y_1,\varphi),\ Y_2^{(1)}(x_1,y_1\varphi) \qquad [4]$$

in which $X_1^{(1)}$, $Y_1^{(1)}$ and $X_2^{(1)}$, $Y_2^{(1)}$ are, correspondingly, the odd and even parts of the functions:

$$X^{(1)}(x_1,y_1,\varphi) \equiv X\cos\varphi - Y\sin\varphi$$

and

$$Y^{(1)}(x_1,y_1,\varphi) \equiv Y\cos\varphi + X\sin\varphi$$

$$X = X(x_1 \cos\varphi - y_1 \sin\varphi,\ x_1 \sin\varphi + y_1 \cos\varphi)$$

$$Y = Y(x_1 \cos\varphi - y_1 \sin\varphi,\ x_1 \sin\varphi + y_1 \cos\varphi)$$

Further proof is given of Eq. [3]. If in Eq. [1] the functions $X(x,y)$ and $Y(x,y)$ are polynomials not having common multipliers, then for the symmetry of the field of the linear elements of Eq. [1] with reference to the straight line [3] it is necessary and sufficient to fulfil the conditions

$$X_1^{(1)}(x_1,y_1\varphi) = 0; \quad Y_1^{(1)}(x_1,y_1,\varphi) = 0$$

identically for X_1 and Y_1.

These propositions are applied to the analysis of Eq. [1] for the cases in which the functions $Y(x,y)$ and $X(x,y)$ are polynomials of the second and third orders. V. A. Pliss

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1904. Yagi, Yu. I., Stability of nonlinear deforming system when there are small end deflections (in Russian), *Trudi Leningr. politekhn. in-ta* no. 178, 100-111, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8582.

The problem on the stability of equilibrium of a nonlinear deforming system with a finite number of degrees of freedom, or of a system leading to the former, expresses itself as a problem for the establishment of the sign and character of the change of values

$$R_i = \frac{\partial}{\partial \varphi_i}(\Pi - P\Psi) \quad (i = 1, \ldots, n)$$

which give the static interpretation (supplementary to the generalized force, essential for maintaining any condition of deformation). Here φ_i are general coordinates, Π is the potential energy of deformation, P is the parameter of external forces, Ψ is the corresponding generalized shift. With the introduction of the relation $c_i = \varphi_i/\theta$, the potential energy appears as a function of one of the generalized coordinates θ. Together with the courses of deformation, corresponding to the given rule of change of external forces, others are also investigated for which $R_i \neq 0$.

If the terminology of author is disregarded, the approach indicated in the article is almost the same as the Poincaré method for investigating the stability of equilibrium in the presence of potential forces. V. V. Bolotin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1905. Dzhanelidze, G. Yu., Stability of equilibrium of nonlinear deformation systems (in Russian), *Trudi Leningr. politekhn. in-ta* no. 178, 112-177, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8583.

The possibility is shown of applying the methods of Poincaré for investigating the stability of equilibrium in the presence of potential forces [P. Appel, "Diagrams of equilibrium of a rotating homogeneous liquid," ONTI, 1936] in problems of stability of nonlinear elastic systems. It is noted that the concepts expressed in the article by Yu. I. Yagi [see preceding review] resemble the method of Poincaré, developed for systems with many degrees of freedom. V. V. Bolotin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1906. Khokhlov, M. A., Bringing equations of motion of nonholonomial systems to a form which permits the last multiple to be unity (in Russian), *Dokladi Akad. Nauk UzSSR* no. 1, 3-7, 1953; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6394.

For equations of motion of a nonholonomial system having linear links a theorem is proved regarding the fact that these equations are transformed to a form which permits the last multiple to be $M = 1$, if the independent variable t is replaced by a new variable τ by means of the equation

$$N^s dt = d\tau, \quad S = \frac{1}{n-m-1}, \quad N = N(q_1, \ldots, q_n)$$

where N is the last multiple of the initial equations and m is the number of equations of nonholonomial links.

The significance of the equation is extremely limited, since, generally speaking, the equations for the last multiple are incompatible even with Chaplygin systems with two degrees of freedom. M. I. Efimov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1907. Livshits, I. E., Theorem of the formation of accelerations (in Russian), Sb. nauch. tr. Leningr. inzh.-stroit. in-ta no. 22, 71-81, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6398.

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1908. Rosenauer, N., Some investigations on the synthesis of a drag-link mechanism having a non-uniformity ratio of 3, *Austral. J. appl. Sci.* **8,** 3, 189-197, Sept. 1957.

In a drag-link mechanism the reduction ratio varies within certain limits. The ratio of these two limits is called the "nonuniformity ratio". For a chosen value of this nonuniformity ratio equal to 3, a complete investigation has been carried out in order to determine the range of possible solutions and the influence of the choice of the parameter ω_{31} on the form and properties of the drag-link mechanism obtained. From author's summary

1909. Istomin, P. A., A generalized method of the approximate kinematic analysis and synthesis of crank mechanisms of piston engines (in Russian), *Trudi Leningr. korablestroit. in-ta* no. 14, 184-199, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6457.

An examination is made of various kinematic arrangements of multi-piston engines in which the working volume of the cylinder is limited by several pistons. The forward movements of these pistons are transformed into the rotational motion of one or several shafts by means of one or several crank mechanisms. In this case the working volume of the cylinder at any time depends on the positions of all the pistons. If the displacement of each of the pistons is expressed approximately in the form of a trigonometric polynomial consisting of two harmonic components, the formula for determining the working volume of the cylinder will assume a form similar to the form of the approximate formula for determining the displacement of the slider in the displaced crank mechanism having regard to the first two harmonic components. On this basis it is recommended that in determining the volume of the cylinder, and also those positions of the mechanism at which the rate of change of the volume of the cylinder is equal to zero, formulas should be used for the "fictive" displaced crank mechanism, the parameters of which are selected from the condition of equality of the coefficients in formulas for determining the volume of the cylinder. For drawing the graphs of the displacements of the pistons and the variation in the volume of the cylinder an instrument is proposed which is a displaced crank mechanism with controlled parameters. It is also suggested that use should be made of the analogy proposed when determining the displacement of the lateral piston in a crank mechanism with a coupled connecting rod. N. I. Levitskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1910. Harding, B. L., Proposed standardized system for notation and classification of the four-bar linkage, ASME Fall Meet., Hartford, Conn., Sept. 1957. Pap. 57-F-28, 8 pp.

1911. MacMillan, R. H., Efficiency of linear mechanisms, *Engineering* 183, 4745, 211–212, Feb. 1957.

A "linear mechanism" is here defined as a transmission (such as a gearbox), in which the power loss can be expressed by a product of the angular velocity of the fastest axle and a quantity $k(ft + T)$, where t is the torque of the fastest axle, T the torque of the slowest axle, and k and f are constants only varying with the reduction ratio R.

From this hypothesis, author has found a relation between the efficiency for ordinary forward motion and that for reverse motion, namely $(1 - \eta_F)^{-1} - (1 - \eta_R)^{-1} = (R - f)/(R + f)$, and a number of diagrams are constructed on this basis. However, all these expressions are without engineering significance, because the factor f is not constant. Its magnitude will vary with the type and the temperature of the lubrication oil, the deformations of the axles, wear and tear, etc. A. R. Holm, Denmark

1912. Litvin-Sedoi, M. Z., Kinematics of free motion of a rectangular trihedron (in Russian), *Vestnik Mosk. un-ta* no. 10, 59–64, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6389.

The free motion of a trihedron is made up of three motions: motion of the peak along a certain curve, rotation of the trihedron with an angular velocity of φ' about an axis, rigidly attached to the trihedron, and rotation of this axis with an angular velocity of λ' about a second axis, also passing through the peak of the trihedron. The first axis describes a conic surface of arbitrary shape about the second axis. Various positions of the axes during the motion of the trihedron are related by angular coefficients with the aid of a matrix expressed by relative angular coordinates. The equation of motion of the trihedron is derived.

L. N. Chekhova
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1913. Lyubatov, Yu. V., Application of the principle of permissible displacement to the calculation of scalar setting error in mechanisms (in Russian), *Trudi in-ta mashinved. Akad. Nauk SSSR* no. 8, 3–17, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7240.

Applying the principle of permissible displacement and denominating the coordinates of the drive link φ, the parameter determining the primary error Δq being q, author arrives at the relationship $\partial\varphi/\partial q = Q$, representing the transmission ratio for the primary error; in this expression Q represents the generalized reactive force corresponding to the parameter q to be determined, on the assumption that the ideal mechanism is in equilibrium under the action of a generalized unit force φ corresponding to the coordinate φ and generalized forces θ corresponding to the generalized coordinate ν of the drive link(s).

In the particular case of translational displacements of a kinematic couple, we have $Q = \pm R$, where R is the projection on the axis along which takes place the displacement of the principal vector of the fictitious reactive forces in the kinematic couple of an ideal mechanism, the displacement whereof is described by the vector Δy; similarly, in the case of rotational (angular) displacement, we have $Q = \pm L$, where L is the principal moment of the same forces about the axis of such rotation.

Author illustrates the generalized theory by three examples.

Ya. L. Geronimus
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1914. Shul'gin, M. F., Theory of linked problems of dynamics (in Russian), *Trudi Sredneaz. un-ta* no. 37, 183–190, 1954; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 6391.

Raus' transformation was performed for holonomial systems with links with cyclic coordinates. The Hamilton-Jakobi equation is derived afresh (from the Ostrogradsky-Hamilton principle) and a linear integral invariant is constructed. I. S. Arzhanykh
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1915. Gaponov, A. V., Transformation of the equations of motion of a dynamic system during the application of ideal links (in Russian), *Trudi Gor'kovsk. politekhn. in-ta* **11,** 1, 75–83, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6390.

Examination of the problem of the transformation of the equations of motion of a dynamic system during the application of the ideal links.

$$\delta x^i = A^i_\alpha \delta y^\alpha$$

where δx^i are the virtual displacements of the system with the links and δy^α are independent virtual displacements.

The transformation of the initial holonomial system is effected and cases of integrated and partially integrated links are examined. In the latter case a conclusion is given for equations of the Chaplygin type and for a wider class including equations of the Chaplygin type. Cases of degenerated links when the number of variables exceeds the number of degrees of freedom of the initial system are examined. B. S. Razumikhin
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1916. Trbojevic, M. D., Load distribution on helical gear teeth, Parts I, II, *Engineer, Lond.* **204,** 5298, 187–190, Aug. 1957; **204,** 5299, 222–224, Aug. 1957.

Papers describe experiments on rubber helical teeth under load. Load distributions along various lines of contact and resulting deflections are presented. Survey of previous theoretical work on gear teeth including load, helix, wear, deformation, and stress intensity is included and definitions and principles are outlined. Paper I sets the scene and carefully describes apparatus, and paper II gives the experiments, results and conclusions. It was found that load distribution along the contact line was uniform within ±2.2% with gear teeth of equal length, and within ±6.3% if of unequal length or axially displaced. Short helical gears, as opposed to spurs, do not act so favorably, and the optimum conditions are defined. P. Whitton, England

1917. Perret, W., Differential gears with planetary gears (in German), *Forsch. Geb. Ing.-Wes.* **23,** 3, 102–106, Feb. 1957.

A general investigation into the properties of planetary gears, mainly covering the transmission ratios and the efficiency of transmission, reveals the special possibilities for the application of such gears to the design of speed change gears. For various types of coupled planetary gears showing good efficiency in all speeds, general equations are derived between their transmission ratios and their number of teeth ratios. The method is outlined in detail by means of several numerical examples, which also allow for a comparison of different types of speed change gears.

From author's summary

1918. Carlsson, B., and Larsson, H., Efficiency and irreversibility of simple epicyclic gear trains, *Trans. Chalmers Univ. Technol.* no. 186, 48 pp., 1957.

The three members of the simple epicyclic gear train rotate with the circular velocities ω_1, ω_2 of the sun gears and ω_3 of the third gear. The power is divided into two parts, the "clutch" power and the "rolling" power P_w, which gives the loss $(1 - y_w)P_w$.

With the parameters $k = \dfrac{\omega_1 - \omega_3}{\omega_2 - \omega_3}$ and $\lambda = \dfrac{\omega_1}{\omega_2}$, the total efficiency η_y of the simple epicyclic gear train is given for $\eta_w = 0.50$ and 0.95

in diagrams. There is also an irreversible region where $\eta_y = 0$. An interesting fact is that irreversible epicyclic gear trains can have efficiencies higher than 0.50. Some numerical examples are given.

In appendix B, Jakobsson gives as an example of the above theory, the Wolfram gear train, which has a high gear ratio and a low efficiency and is irreversible. L. Foppl, Germany

1919. Beletskii, V. Ya., Analytical method of determining the curvature of projected plane cams (in Russian), *Trudi Odessk. tekhnol. in-ta* **7,** 19-26, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6460.

By means of a variable four-term process with minimum pairs a formula was obtained for calculating the curvature of the theoretical profile of the cam. A number of particular cases were examined. S. G. Kislitsyn

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1920. Mal'tsev, V. F., Determination of the shape of the roller of three-dimensional cylindrical cam mechanisms (in Russian), *Trudi Odessk. tekhnol. in-ta* **7,** 47-52, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6458.

Examination of the problem of determining the shape of a roller and the surface of a cam groove, in which rocking of the roller without slipping is noted. Recommendations relating to the reduction of slipping when it cannot be avoided are given. The explanation is supplemented by a numerical example.

S. G. Kislitsyn

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1921. Ezikashvili, O. S., Minimum clearances of cam mechanisms (in Russian), *Trudi Gruz. politekhn. in-ta* no. 34, 25-30, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6461.

Using V. T. Kostitsin's method, author derives equations with the aid of which it is possible to determine the minimum radius of the cam and individual design dimensions of the mechanism in the case of a sinusoidal law of variation of acceleration of the push rod. K. Kh. Shakhbazyan

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Servomechanisms, Governors, Gyroscopics

(See also Revs. 1881, 2293, 2359)

1922. Loeb, J. M., Survey of mathematical methods for nonlinear control systems, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-104, 12 pp.

Paper briefly surveys the various mathematical methods available for the study of the nonlinear ordinary differential equations governing control systems. Methods are indicated for finding limit cycles and for discussing their stability. The behavior of circuits under random input disturbances is touched upon. Throughout, control circuit systems are used to illustrate the methods.

A. F. Pillow, Australia

1923. Thomson, W. T., Analog computer for nonlinear system with hysteresis, *J. appl. Mech.* **24,** 2, 245-248, June 1957.

Structural materials loaded beyond the elastic limit generally display a hysteresis effect such that recovery from maximum deflection proceeds elastically. Assuming a spring-mass model for such a structure to exist, where the stiffness is represented by segments of straight lines, its solution under dynamic excitation still offers sufficient difficulties to welcome a computer technique which will automatically perform this task. This paper describes an electronic analog computer scheme which will carry out such a solution for an unidirectional force excitation.

From author's summary

1924. Lieberman, D. A., How proportional plus integral control stabilizes, *Automation* **4,** 6, 77-84, June 1957.

Author describes various elementary controllers and a more satisfactory, complex mode of control, then proceeds to analyze equipment designed to perform in this mode.

From author's summary

1925. Kempe-Nemm, A. A., Comparative analysis of certain improved methods to two-position control, *Automation and remote Control, USSR* **17,** 8, 753-773, Aug. 1956 (Consultants' Bureau Translation *Avtomatika i Telemekhanika* **17,** 8, 665-680).*

Since the two-position control of a furnace is described by a first-order system, graphical construction of the temperature-time curve is simple. Different additional devices for diminishing the amplitudes of steady-state oscillations are investigated in all details. I. Flugge-Lotz, USA

1926. Tsypkin, Ya. Z., Automatic control systems containing digital computers, *Automation and remote control, USSR,* 735-751, 1957 (Consultants' Bureau Translation *Avtomatika i Telemekhanika* **17,** 8, 680-699, Aug. 1956).*

Linear closed loop control systems containing digital computers as well as analog elements are classified in three sets according to the position of the computer with respect to the comparator or differential, namely as an input to the comparator, or in the closed loop, or as a comparator. In addition, the theory is restricted to linearly programmed computers so that the output is related to the input by a linear difference equation. The equivalence of such systems to pulse control systems is established, and formulas for the transfer functions for each of the above classes are computed.

The dynamic properties of these systems are studied under two general classifications. For the class for which the bandwidth of the computer is greater than the bandwidth of the analog or continuous elements, it is shown that the dynamic properties of the control system are essentially equivalent to the dynamic properties of a system without a computer. For the other class, i.e. when the bandwidth of the computer is less than the bandwidth of the analog elements, the dynamic properties are shown to be not equivalent to the dynamic properties of a continuous system and that the computer can be used as a pulse corrector. The relation of these remarks to the sampling theorem of communication theory is indicated. J. Hrones, USA

1927. Aizerman, M. A., The problem of determining periodic conditions in systems of automatic regulation (in Russian), Trudi 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. Vol. 1. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 105-130; *Ref. Zh. Mekh.* 1956, Rev. 5745.

The survey contains the following sections: (1) The importance of the problem of determining periodic conditions; (2) the history of the matter; (3) the place occupied by the problem of periodic conditions in the general complex of nonlinear problems in the theory of regulations; (4) statement of the problem of the determination of periodic conditions; (5) approximate methods for determining periodic conditions; (6) the theory of periodic conditions in relay systems; (7) periodic conditions in cases where the characteristics of an arbitrarily harmonized linear system are present; (8) systems near to periodic conditions; (9) the formulation of the fundamental problems.

*Paper available only from Consultants Bureau, New York.

It is shown that the tendency of systems of automatic regulation to develop self-excitation, to generation of oscillation lies in the very nature of these systems, as in the system with feedback. In the cases of self-excitation, the systems of regulation are entirely inadmissable; in the cases of others, self-oscillation systems depend basically on the correct work of the regulator (vibrating regulators). The estimate of effectiveness of both types of systems of regulation requires study of the dynamics of the systems and, in particular, the determination of the periodic conditions.

It is noted that the determination of periodic conditions in view of the present stage of development of the theory follows regular methods in the following three cases:

(1) In systems in which the periodic oscillations approach the sinusoidal (approximate to the method of Poincare, Vanderpol, N.M. Krylov, and N.N. Bogolyubov and others). The nearness of the self-oscillations to the sinusoidal is dependent on whether the "linear part" of the system manifests itself either as a resonance system or as a filter of the lower harmonies—and cuts off, more or less effectively, all the harmonics of the periodic oscillation (with the exception of the fundamental).

(2) For relay systems consisting of a linear part and a relay construction, there are available accurate methods of finding periodic conditions (A.I. Lur'e, Ya.I. Neimark). The simplest have been found to be symmetrical periodic systems.

(3) For subdivided linear systems (systems with subdivided-linear characteristics), a full investigation of the dynamics and, in particular, the determination of the periodic oscillations can be carried out by the method of point transformation (A.A. Andronov and others). A large number of problems on different systems of automatic regulation has been solved by this method, which can be described as differential equations of the second and third degree.

In conclusion, the basic problems confronting the theory of automatic regulation are formulated. The solution of these would permit a marked forward step in determining oscillatory movements and in reaching methods of determination of such movements for simple engineering procedure.

N. A. Zheleztsov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1928. Kitaev, B. I., Lomakin, L. M., and Madison, V. G., The conditions governing stability of rapid systems of regulation (in Russian), *Trudi Ural'skogo politekh. in-ta* **53**, 61–64, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5739.

Authors show the relationship of statistically stable systems, in which the time of retardation of the regulator is considerably greater than the time of self-equalization, to the rapid systems of automatic regulation.

The problem emerges of the selection of a regulator (possessing a zone of insensitivity) which would be near realization of the monotonous process of regulation for such systems. Authors conclude that, in order to attain this, the most suitable regulators are those in which the speed of regulation is proportional to the deviation of the value capable of regulation from the given program.

E. N. Miroslavlev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1929. Ezekiel, F. D., The effect of conduit dynamics on control-valve stability, ASME Semiann Meet., San Francisco, Calif. June 1957. Pap. 57-SA-50.

A method is presented for simulating the dynamic behavior of a frictionless hydraulic conduit with distributed parameters in conjunction with a simple spool-type control valve for analog-computer use. Analytical and experimental results showing the regions of stable and unstable operation of such a system are given, together with suggested stabilizing techniques. The effect of the valve chamber in the over-all analysis is found to be of considerable importance.

From author's summary

1930. Ryabov, B. A., On the change of parameters in the self-oscillation conditions of some nonlinear servo-systems (in Russian), *Trudi MAI* **41**, 134–140, 1955; *Ref. Zh. Mekh.* 1956, Rev. 5738.

Investigation is made of the change in the conditions of self-oscillation at the expense of variations of parameters of function of direction of relay. Author develops the method he put forward for the computation of parameters in auto-oscillation of relay servo-systems [*Dokl. Akad. Nauk SSSR* **81**, no. 4, 1950] and introduces auxiliary graphical constructions, which simplify the calculation of the period and amplitude of the self-oscillation, and also an analysis of the influence of the parameter system and the function of direction of relay ξ on the formation and suppression of self-oscillation.

G. M. Ulanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1931. Dudnikov, E. G., Method for determining the optimum settings of industrial control systems by means of experimental dynamic characteristics (in Russian), Avtomatizatsiya proizvodstvennykh protesessov, Moscow, Izd-vo Akad. Nauk SSSR, 13–33, 1955; *Ref. Zh. Mekh.* 1956, Rev. 4996.

A method is suggested for selecting parameters of control of a known type for the case when the dynamics of the object is given by its amplitude—phase characteristic, which is known from calculation or from experiment. The whole system is considered linear.

The settings of the regulators at which the degree of damping of the partial components of the solution is not less than that given are determined according to the known characteristic of the object. Preciseness of the settings is obtained by minimization of the integral

$$I = \int_0^\infty [y(t) - y(\infty)]^2 \, dt$$

in which $y(t)$ is the value of the controlled dimension, $y(\infty)$ is its value in the new state of equilibrium of the system.

Examples are given for several types of regulator.

A. A. Fel'dbaum

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1932. Tsypkin, Ya. Z., Asymptotic properties of some non-single contour systems of automatic control (in Russian), *Trudi Vses. zaoch. energ. in-ta* **6**, 10–16, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6421.

Paper examines system of control in the presence of an internal feedback link produced by an element the transmission function of which represents a relationship of polynomials according to p.

For non-single contour systems of this type, unlimited increase of the amplification coefficients of the separate elements, theoretically speaking, does not disturb the stability of the system as a whole.

In this connection the physical nature and certain asymptotic properties of systems of this type are elucidated.

Yu. I. Mitropo'skii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1933. Tal', A. A., Influence of auto-control and action according to a derivative on the process of direct control (in Russian), Pamyati Aleksandra Aleksandrovicha Andronova, Moscow, Izd.-vo Akad. Nauk SSSR, 1955, 282–299; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6422.

Developing the investigation by A. A. Andronov and A. G. Maier [*Doklady Akad. Nauk SSSR* **42**, no. 5, 1945; *Avtomatika i Telemekhanika* **8**, no. 5, 1947; *Ref. Zh. Mekh.* 1955, Rev. 1187] of I. A. Vyshnegradskii's problem in the theory of direct control, author considers the influence on the regulator of the variation in the rotational speed of the machine, and in addition assumes that the system has auto-control.

First, the result is given of the investigation of the linear model when the influence of dry friction can be disregarded. Diagrams are given of the regions of stability and of the region of a finite number of oscillations according to different pairs of practically convenient parameters, which enables their influence on the stability to be seen directly. This investigation has a secondary character which serves primarily for showing the role of dry friction on the process on control.

Then the results are given of the investigation of the nonlinear problem, which is solved by means of bringing the plane to a point transformation. For investigation of the oscillations corresponding to the finite number of oscillations in the corresponding linear system, a Lyapunov function is constructed which makes it possible to determine the absolute stability. The basic result of the investigation of the nonlinear system consists in separating in space the parameters of the system of five regions, essentially different from the point of view of the efficiency of the system of control: the regions of absolutely stable rest, conventionally stable rest, absolutely stable self-oscillations, conventionally stable self-oscillations, and absolute instability.

Yu. I. Neimark

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1934. Krasovskii, A. A., Some problems of the synthesis of systems of automatic control by the method of transitional functions (in Russian), Trudi 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. Vol. 2. Moscow-Leningrad, Izd-vo. Akad. Nauk SSSR, 1955, 105–116; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6423.

Author proposes a new method of synthesis of control systems which makes it possible to select the necessary transitional function of the correction term if the transitional functions of the remaining members are known, and the required transitional function of the closed automatic system is given.

The basis for this method of synthesis is provided by fairly simple algebraic formulas, from which it is possible to calculate the points of the transitional function of a closed system according to the given transitional functions of an open system or of specific terms. The formulas of this numerical method, which are also of independent scientific interest, were obtained by the author together with G.S. Pospelov on the basis of the examination of linear integral estimates and of the Laplace transformation. It is shown that the accuracy of the calculation according to one of the formulas proposed is greater than that given by Prasad's formula, which is based on the replacement of the Duhamel integral by the sum of the trapezia.

E. P. Popov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1935. Dudnikov, E. G., Investigation of the qual'ty of the process of control according to the dynamic characteristics of the elements of the system found by experience (in Russian), Trudi 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. Vol. 2. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 500–513; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6430.

An exposition of approximate methods of investigating systems of automatic control according to the experimental dynamic characteristics of the object of control and of the control apparatus.

A description is given of a method of treating the experimental frequency characteristics which is based on the use of harmonic analysis. In order to facilitate consideration of the linear and nonlinear distortions introduced by the measuring apparatus, it is recommended that the experimentally determined family of primary amplitude-phase characteristics of the apparatus used should be employed.

Two methods of evaluating the quality of the control process according to the transitional characteristics of the object are examined. One method is based on comparison of the transitional characteristic with the choice of the type characteristics, the equations of which were known previously. The essence of the second method consists in the construction according to the transitional characteristic of the given object of an approximate transmission function of the object. A short evaluation of the accuracy of the calculation formulas obtained by different authors is given.

The possibility is indicated of frequency methods of evaluating the quality of the control process. Relationships are given which make it possible to construct curves of transitional processes from the experimental data.

A. A. Ovchinnikov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1936. Chernozhskaya, L. N., On the influence of the matching of the automation parameters on the self-oscillation of the governing system (in Russian), *Uchen. zap. Mosk. un-ta* **172**, *Mekhanika* **5**, 191–205, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5751.

By means of the method of the small parameter in the form put forward by B. V. Bulgakov, an investigation was made on the oscillations of a nonlinear system of governing.

In the range of parameters regions separate out in which steady self-oscillations are possible. The stability of the latter is checked by the method of averaging.

E. N. Miroslavlev, USSR

Courtesy Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1937. Nightingale, J. M., Hydraulic servo fundamentals 1, Cleveland, O., Mach. Design, 1957. (Reprinted from *Mach. Design*, 1956)

Volume I consists of five papers which provide a review of basic servo theory. Reviewer regards material as too brief for the novice yet too elementary for someone with formal training in automatic regulation. Good textbook references are given.

S. Z. Dushkes, USA

1938. Nightingale, J. M., Hydraulic servo fundamentals 2, Cleveland, O., Mach. Design, 1957. (Reprinted from *Mach. Design*, 1957)

Volume II consists of six papers devoted principally to four-way valve servos. Method of small perturbations is used to obtain transfer functions that provide good approximation of dynamic response. Static characteristics are considered also, and many useful design criteria are developed. Bibliography is quite incomplete.

S. Z. Dushkes, USA

1939. Estrada, A. de la C., Time lags in hydraulic and pneumatic valves (in Spanish), *Anal. Mecan. Electr.* **34**, 1, 3–17, Jan.-Feb. 1957.

1940. Ivashchenko, N. N., On the evaluation of the hydrodynamic link in chain regulation (in Russian), *Sb. nauch. rabot Mosk. inzh-fiz. in-ta* no. 7, 137–155, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5748.

An account is given of the evaluation of a typical hydraulic booster. Nonlinear differential equations are deduced which describe the transitional processes in the element constituting the hydrobooster when definite simplifying assumptions are made, particularly in regard to the assumption of the steadiness of the

coefficient for the consumption of fluid over the valve of the booster. The method is given for estimating the basic parameters and the statistical characteristics of the booster at given dimensions for adjustment of the piston of the valve and servomotor based on equations of the statics of the booster. The stability of the work of the hydrobooster is examined by the method of linear approximation.

Examples are given to illustrate the method of determining parameters and characteristics of the hydrobooster. Author shows that to acquire greater precision of the described method it is necessary to carry out experimental work to study the coefficient of consumption. I. M. Smirnova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1941. Fricke, C. L., A thermocouple subcarrier oscillator for telemetering temperatures from pilotless aircraft, *NACA TN* 4128, 50 pp., Dec. 1957.

1942. Stevens, F., and Lynch, F. W., Aids to inertial navigation, *Aero. Engng. Rev.* **16,** 11, 43–47, Nov. 1957.

1943. Smith, D. N., Statistical methods for machine-tool feedback gaging, *Control Engng.* **4,** 9, 190–196, Sept. 1957.

1944. Bankovskaya, N. V., The stability of the axis of a heavy gyroscope with the shaft in a vertical position, in the presence of harmonic oscillations of the point of support (in Russian), *Ukr. mat. Zh.* **6,** 4, 418–422, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5716.

An examination is made, using a linear arrangement, of the stability of a heavy gyroscope rotating uniformly round a vertical axis in the presence of harmonic oscillations of the point of support. The equations in modified forms lead to the equation of Mat'e Khilla.

The sequence of zones of stability and instability in the plane of two parameters of the equation is derived from the conditions of the periodicity of the solutions. Curves are given to show the influence of the parameters of the gyroscope and the frequency of the forced oscillations on the shape of the region of stability.

Formulas are established for a characteristic indicator such as the function of the frequency of the forced oscillations and the parameters of the gyroscope in the two main regions of instability. L. A. Rozenberg

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1945. A theorem of N. E. Zhukovsky, and A. N. Obmorshev. Elements of the theory and calculation of gyroscopic and navigational instruments (in Russian), (MVTU **48**), Moscow, Oborongiz, 1955, 82–83; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7164.

Proof is given of the statement by N. E. Zhukovsky regarding the motion of the point of intersection of the axis of rotation on an ellipsoid of inertia of a body rotating about a fixed point with a sphere described about its center with a radius equal to the radius of inertia of the body about the equatorial diameter of the ellipsoid of inertia.

The proof consists in a formal transformation of the Euler equations into the equations of motion of the aforesaid point in which the mass of the body is assumed to be concentrated. G. N. Sveshnikov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1946. Sergeev, M. A., Investigation of a two-stage gyro-compass with air ball bearings (in Russian), Thesis, Leningr. in-ta technoi mekhan. i optiki, 1956; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6401.

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1947. Topcheev, Yu. I., Practical methods of synthesis for correcting appliances of following systems (in Russian), Trudi 2-go Vses. soveshch. po teorii avtomat. regulirovaniya. Vol. 2. Moscow-Leningrad, Izd-vo Akad. Nauk SSSR, 1955, 264–265; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6425.

Courtesy Referativnyi Zhurnal, USSR
Translation, Courtesy Ministry of Supply, England

1948. Alekseev, A. S., Two-position temperature regulator with an advance zone (in Russian), Pamyati Aleksandra Aleksandrovicha Andronova, Moscow, Izd-vo Akad. Nauk SSSR, 1955, 45–76; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6436.

Operating conditions are examined of a two-position regulator having an advance zone, taking into consideration the information delay between the furnace to the regulator. An examination is made of the phase space, constructed from sheets of the plane which correspond to the regions of different values of the characteristics of the regulator, while as a result of delay during the putting together of these sheets certain additional regions are introduced. The investigation is reduced to study of the point transformations in the phase space.

The experiment performed on the laboratory furnace well substantiated the qualitative conclusions of the theory. The problem of finding the limits of the regions of the parameters corresponding to the different conditions is rapidly and adequately solved on an electronic model, a short description of which is given. The exposition is illustrated by oscillograms. N. N. Krasovskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1949. Kasprzhak, G. M., and Shchitova, V. M., Structural classification and comparative analysis of systems of automatic control of the process of arc welding (in Russian), *Trudi sektsii po nauch. razrabotke problem elektrosvarki i elektrotermii Akad. Nauk SSSR* no. 1, 31–56, 1953; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6442.

A classification is given of the possible systems of control of the process of arc welding according to their structure. On the basis of the method proposed by the authors, an arrangement of a system of control of arc welding is constructed for the general case, expressions are given for the coefficients of the terms which make up this arrangement, and expressions are given for the static errors for various particular cases of a generalised structural arrangement and various points of application of the disturbing effects. The dynamic properties of systems of various classes are estimated in a rough approximation. A comparative analysis of different classes of systems is made on the basis of comparison of their static and dynamic properties. I. M. Smirnova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1950. Neimark, Yu. I., On the periodic movements of relay systems (in Russian), Recollections of Aleksandra Aleksandrovicha Andronova, Moscow, Izd-vo Akad. Nauk SSSR, 1955, 242–273; *Ref. Zh. Mekh.* 1956, Rev. 5746.

Paper deals with the study of free and forced movements of relay systems consisting of linear links and so-called relays. Equations are deduced for the movement of the relay system with the help of point transformation of an infinite space into itself; the classification of periodic movements is established and equations are given for a periodic condition of a given type; the existence is established of compact periodic movements in relay systems; the stability of periodic movements is investigated. The last merges into the problem of the distribution of the roots of the so-called characteristic function relative to the unitary ring. S. V. Kalinin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1951. Ivashchenko, N. N., A statistical evaluation of basic parameters of speed governors at a given degree of irregularity and adjustable force on the sleeve (in Russian), *Sb. Nauch. rabot Mosk. inzb.-fiz. in-ta* no. 7, 105–136, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5749.

A method is developed for determining basic constructive parameters of certain existing typical speed governors at prescribed values of mean rpm, degree of unsteadiness of the governor, the force required for shifting its sleeve, and degree of insensitivity of the governor.

The means of evaluation are based on the possibility of examining the kinematics and statistical characteristics of a typical governor of selected construction, similar to the governor of which the parameters have to be determined (by the expression "similar governor" is understood a governor in which the length of the corresponding links of the mechanism are proportional).

A method is demonstrated for evaluation of centrifugal governors with heavy sleeves without springs, of centrifugal governors with vertical and horizontal springs, of a plane governor with rocking masses, of plane governors of both modifications with gradually changing masses, and also a method of evaluation for a hydraulic speed. A series of examples of the evaluation is given.

I. M. Smirnova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1952. Belousov, T. T., Automatic regulation of tension of a metallic strip while in a cold-process metal-rolling mill (in Russian), *Sb. nauch. rabot. Mosk. inzb.-fiz. inta* no. 7, 41–63, 1954; *Ref. Zh. Mekh.* 1956, Rev. 5752.

An examination is made of a system of regulating the current being fed to the armature of a motor with the aid of an angular regulator, with certain simplifying assumptions. Linear differential equations of the elements of this system are formulated, resulting in a system of the ninth order.

The influence of the separate parameters on the stability of the system was studied with the aid of the D-splitting method, when the question of the stabilizing transformer is discarded, while the equation of the regulator is replaced by the equation of its statistical characteristic, with the net result that the equation is reduced to the fourth order. I. M. Smirnova

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1953. Herr, R. W., A wide-frequency-range air-jet shaker, *NACA TN* 4060, 15 pp., June 1957.

A simple shaker which obtains its driving force from streams of high-velocity air is described. This air-jet shaker has the following advantages: its force can be calibrated statically and appears to be constant with frequency; it is relatively easy to use; and it has essentially massless characteristics. With this shaker it is possible to define the unstable branch of a frequency-response curve obtained with a nonlinear spring.

From author's summary

1954. Coales, J. F., Some principles of measurement and control, *J. sci. Instrum.* **33,** 12, 457–464, Dec. 1956.

1955. Farquharson, J., and Kermicle, H. A., Precise automatic manometer reader, *Rev. sci. Instrum.* **28,** 5, 324–325, May 1957.

An instrument has been developed to automatically find the level of mercury in a glass tube and indicate on a digital register the height of the mercury column. The first model has a range of 80 cm, a precision of better than ± 0.05 mm, and a maximum deviation of ± 0.11 mm. The range and deviation depend upon the length and linear accuracy of the metric screw.

From authors' summary

1956. Holzbock, W. G., The static behaviour of industrial measuring and control devices (in German), *Regelungstech* **5,** 4, 118–122, 1957.

1957. Bennett, F. D., The Controlled-Temperature-Pressure Range, *Aero. Engng. Rev.* **16,** 10, 63–68, Oct. 1957.

A survey is given of the research and development program which has culminated in operation of the Controlled-Temperature-Pressure Range (CTPR) for production of flows up to Mach 11. Methods of control of temperature and pressure in the 45-ft working section are described. The instrumentation necessary for measurement of (1) projectile drag coefficient and (2) density throughout the field of flow is discussed. From author's summary

1958. Soo, S. L., and Charters, W. W. S., Dynamic response characteristics of gas turbines, ASME Fall Meet., Hartford, Conn., Sept. 1957. Pap 57-F-22, 17 pp.

Generalized study shows functional relations of basic design parameters affecting dynamic stability of gas turbines. Such parameters are compressor stability, component efficiencies, maximum cycle temperature, cycle-pressure ratio, compressor-flow coefficient, turbine-flow parameter, cycle-pressure drop, design speed, inlet condition, rotational inertia, and hub-to-tip-diameter ratio. Significance of proper proportioning of flow characteristics in split turbine design is pointed out. Effect of thermal lag in regenerator on fuel requirements and runaway characteristics are considered. Discussion includes multishaft or twin-spool arrangements and favorable dynamic characteristics of closed-cycle plants. From authors' summary

1959. Rothbart, H. A., A numerical method for determining cam-follower response, ASME Fall Meet., Hartford, Conn., Sept. 1957. Pap. 57-F-17, 7 pp.

Because of a trend toward higher speeds, heavier loads, and greater accuracy in mechanisms and machines, there has arisen a need for determining the actual response of a cam-driven follower. The shape of the cam curve may be given in any form; graphically, analytically, or numerically. The numerical method described in this paper has been used successfully in practice, is simple to apply, and provides rapid analysis of the follower displacement, velocity, acceleration, and force curves. It also considers the fabrication accuracy of the cam contour. Furthermore, because of its fundamental approach the procedure may be applied to any mechanism or combination of links; e.g., quadric trains, gears, and chains, to determine the position of the members during high-speed and/or high-load operation.

From author's summary

1960. Sherrard, E. S., Simulator for use in development of jet engine controls, *Nat. Bur. Stands. Circ.* no. 584, 17 pp., Sept. 1957.

A method of simulation and cost estimates of simulator components are given for a simulator to be used in the development of turbojet engine control systems for aircraft. The simulator employs typical d-c analog computer components. It is capable of representing a twin-spool, variable-nozzle, afterburning turbojet engine, as well as the engine's controller. The simulator is of moderate accuracy flexibility, and cost. It is intended to be used in the determination of the stability and performance of the engine control system. From author's summary

1961. Cleland, W. W., Automatic temperature control for an adiabatic calorimeter, *Rev. sci. Instrum.* **28,** 9, 696–698, Sept. 1957.

An automatic temperature control device for an adiabatic oxygen bomb calorimeter has been developed which keeps the temperature of the outer water jacket equal to that of the inner bath. When the

temperature of the inner bath is not changing rapidly, heat losses are negligible; however, the error due to lag when the inner bath temperature is rising rapidly is about two parts per thousand. This degree of precision permits the accurate analysis of samples of low caloric content such as lyophillized urine. Since the technician need not watch the calorimeter once the bomb has been fired, but instead can prepare a second bomb, the number of samples analyzed in a given time can be doubled if two bombs are available for use with the calorimeter.

From author's summary

1962. Sanders, J. C., Novik, D., and Hart, C. E., Effect of dynamic characteristics of rocket components on rocket control, *Aero. Engng. Rev.* **16,** 10, 73–77, Oct. 1957.

The contributions of the dynamic properties of the thrust chamber, propellant lines, and pumping system to the stability and controllability of the rocket power plant are explored. Particular attention is given to the extent of understanding contained in the literature. From authors' summary

1963. Haeussermann, W., Stability areas of missile control systems, *Jet Propulsion* **27,** 7, 787–795, July 1957.

Areas of stability are derived for missile control systems with linear and nonlinear servo components. Methods are shown to adapt signal phase shifting networks to the properties of the missile and a selected servo system. The investigations are extended to missile motions around its center of gravity and about a prescribed line of flight. From author's summary

1964. Schuerger, T. R., Computing-control applied to sintering process, *Control Engng.* **4,** 9, 130–133, Sept. 1957.

1965. Lieberman, D. A., Computing-control applied to wind tunnel, *Control Engng.* **4,** 9, 134–137, Sept. 1957.

1966. Pfister, R. C., and Buder, E. E., Computing-control applied to airborne fire-controller, *Control Engng.* **4,** 9, 138–140, Sept. 1957.

1967. Dornbusch, P. E., Computing-control applied to tapered-sheet leveler, *Control Engng.* **4,** 9, 141–143, Sept. 1957.

1968. Engel, H. L., Computing-control applied to fractionating column, *Control Engng.* **4,** 9, 144–147, Sept. 1957.

1969. James, E. W., and Boksenbom, A., Background for computing-control: characterizing the process, *Control Engng.* **4,** 9, 148–159, Sept. 1957.

1970. Russell, D. W., McGregor, W. K., and Burns, L. F., Background for computing-control: how analog computing functions control the process, *Control Engng.* **4,** 9, 160–165, Sept. 1957.

1971. Tierney, J. W., Holman, C. J., Nemanic, D. J., and Amundson, N. R., Background for computing-control: how digital computing functions control the process, *Control Engng.* **4,** 9, 166–175, Sept. 1957.

1972. Maze, R. A., Background for computing-control: converting process information into controller inputs, *Control Engng.* **4,** 9, 176–182, Sept. 1957.

1973. Salzer, J. M., Background for computing-control: from controller output to process actuation, *Control Engng.* **4,** 9, 183–189, Sept. 1957.

Vibrations, Balancing

(See also Revs. 2087, 2170, 2182)

Book—1974. Hubner, E., Technology of vibrations [Technische Schwingungslehre in ihren Grundzügen], Berlin, Springer-Verlag, 1957, xi + 322 pp.

Starting at an elementary level, the book can be recommended as a good introduction to the wide field of mechanical vibrations. Of course, complex notation is used; but all mathematical developments are rather simple and so detailed that even a beginner will have no difficulty in following. Nevertheless numerous important technical problems are well treated; e. g., vibrations of elastic solids, gases and liquids, and even some problems of nonlinear vibrations. One chapter deals with electrical analogies. For illustration the reader will find a great number of completely solved numerical examples. Both mechanical and civil engineers will find the book of good use.

F. Chmelka, Austria

1975. Golovnin, G. Ya., Oscillations of a point, having regard to the force of friction (in Russian), *Nauch. zap. L'vovsk. politekhn. in-ta* no. 17, 139–146, 1953; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6415.

The particular integrals of the equation

$$m\ddot{x} + b\,|\dot{x}|\,\nu\dot{x} + cx = P \sin \omega t$$

in which m, b, c, ν and P are constants, are sought by the method of N. M. Krylov and N. N. Bogoliubov.

A. P. Duvakin

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1976. Pisarenko, G. S., The theory of oscillations of nonlinear systems of the hysteresis type (in Russian), *Izv. Kievsk. politekhn. in-ta* **15,** 112–125, 1954; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8536.

A method is developed for calculating systems of oscillation with distributed parameters with reference to dispersion in the material at the expense of hysteresis losses when loading is cyclic.

Arising from the nonlinear run of the problem, nonlinear differential equations are deduced for the solution of which application is resorted to the asymptotic method of nonlinear mechanics. Formulas are deduced for the construction of resonance curves.

Yu. A. Mitropol'skii

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1977. Rubanik, V. P., Passing through resonance in a nonlinear system having two degrees of freedom (in Russian), *Stud. nauk. pratsi Kiivs'k. in-ta* no. 16, 107–117, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6413.

A disturbing force is assumed with several harmonic components which almost simultaneously resonate with both natural frequencies of the system. For the investigation, N. M. Krylov and N. N. Bogoliubov's method is used ["Introduction to nonlinear mechanics," Kiev, Izd-vo Akad. Nauk Ukr. SSR, 1937]. The system of equations of the first approximation is integrated by numerical methods. A numerical example is examined.

L. N. Chekhova

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

1978. Galkin, M. S., On the solution of the Cauchy problem for a certain equation (in Russian), *Prikl. Mat. Mekh.* **20,** 2, 271–278, Mar.-Apr. 1956.

Author considers solution of the following initial-value problem

$$[au''(x)]'' - bu(x) = 0,$$

in the interval (0, 1), where a and b are positive functions of x, which together with their first derivatives are continuous in the given interval. This kind of differential equation controls transverse vibrations of beams. In general the problem has to be solved by some approximate method. If the solution happens to be oscillatory then an approximation would very likely contain large errors. Author makes a rigorous analysis of the generation of errors in such a case. He shows that when the functions $a(x)$ and $b(x)$ are not constants the general solution will contain terms with $\exp(x)$ and $\exp(-x)$. He also shows how to obtain those terms and how to exclude them from the solution. The results are contained in three theorems with long and quite involved proofs.

T. Leser, USA

1979. Malvern, L. E., Effect of damping on vibration frequencies of simple systems, Proc. Third Midwestern Conf. on Solid Mech., Univ. of Mich., Apr. 1957, 195–205.

Author demonstrates that viscous damping parallel to part of spring of linear single mass vibratory system may raise or lower frequency of displacement resonance. Interestingly, it must always raise frequency of velocity resonance.

R. Plunkett, USA

1980. Lordkipanidze, R. S., The calculation of vibration frequencies (in Russian), *Comm. Akad. Nauk Gruz. SSR* **15,** 2, 99–106, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6930.

The application of the method of "spectral functions" [S.A. Bernstein: "A new method of calculating the frequency of vibration of elastic systems," Moscow, Military Engineering Academy, RKKA, 1939] is described for determining the mode of vibration of columns of variable cross section.

F. M. Dimentberg

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1981. Clarc, D., On the iterative calculation of higher natural modes. Part II (in French), *Recb. aéro.* no. 56, 33–40, Feb. 1957.

This is a continuation of an earlier paper of the same title [AMR **10,** Rev. 2779] in which the theoretical aspects of the method were discussed. Part 2 presents a study of the precision of the process and a numerical example.

F. W. Niedenfuhr, USA

1982. Moseenkov, B. I., Oscillations of systems with distributed parameters when passing through resonance (in Russian), *Stud. nauk. pratsi Kiivsk. in-ta* no. 16, 49–64, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6409.

Using a method explained in the work of Yu. A. Mitropol'skii [*Ukr. matem. Zh.* no. 2, 1948], author finds a solution for linear dynamic systems with many degrees of freedom and slowly varying coefficients for the case of fundamental resonance. Having shown that it is possible to obtain the same results by the energetics method, author gives an example of the application of this method to linear systems with distributed parameters (oscillation of a girder under the action of a slowly displaced load and a disturbing force.)

I. V. Pyshkin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1983. Blekhman, I. I., The problem of stability of periodic solutions of quasi-linear systems with many degrees of freedom (in Russian), *Dokladi Akad. Nauk SSSR (N.S.)* **104,** 6, 809–812, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6405.

Investigation of the stability of periodic solutions for a quasi-linear nonautonomous system

$$\frac{dx_s}{dt} = \lambda_s x_s + f_s(t) + \mu F_s(x_1, \ldots, x_l, \mu, t)$$

$$(s = 1, \ldots, l)$$

where F_s are the analytical functions $x_1 \ldots x_l$ in a certain region G to which all the periodic solutions examined belong, and of the parameter $\mu \geq 0$ at fairly low values of it. In respect of t the functions f_s and F_s are continuous and have the period 2π.

The characteristic equation of system [1] at $\mu = 0$ has a zero root of k multiple, p pairs of purely imaginary roots of the form $M_j\sqrt{-1}$ with degree of shortness m_j ($j = 1, \ldots, p$), where the numbers N_j and their differences differ from whole numbers and from zero. The real portions of the other roots are assumed to be negative.

During the proof of the theorem of stability of the periodic solution, author permits an erroneous assertion to the effect that the roots of the characteristic equation [13], which at $\mu = 0$ become unity, will be analytical functions. The same can be said of the roots of equation (12), which at $\mu = 0$ becomes

$$\exp(\pm 2\pi N_j\sqrt{-1})$$

The assertion of the author will be true if, for example, all the roots of equations (7) and (8) are simple ones.

S. N. Shimanov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1984. Obmorshev, A. N., Oscillations and steadiness of nonholonomial systems (in Russian), "Mekhanika", (MVTU **50**), Moscow, Oborongiz, 1956, 75–96; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8042.

Small oscillations of a nonholonomial system about the equilibrium position and about the position of steady motion are examined. In the first case, equations with indeterminate multipliers are used; in the second, the equations of S. A. Chaplygin. By analogy with holonomial systems, conceptions are introduced of coefficients of inertia, rigidity, gyroscopic and pseudo-gyroscopic moments. An expression is derived for the characteristic equation. The example chosen for demonstration is the motion of a four-wheel bogie along a rectilinear railway track.

V. S. Novoselov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1985. Ziemba, S., Dry friction vibration damping (in English), *Arch. Mech. stos.* **9,** 3, 275–291, 1957.

Paper is concerned with an exact description of method of damping of the dry friction type, in the case of free vibration of a system of one degree of freedom. Considerations are based on an accurate scheme of dry friction, in contrast to the common over-simplified diagram containing a discontinuity at the change of the sign of the instantaneous speed.

The actual process is much more complicated, as it involves two values of the frictional resistance in the neighborhood of the inversion points, where the speed passes through zero. Using qualitative analysis, author constructs by means of Lienard's method the phase trajectory of such a motion, thus enabling it to be compared with a motion that would result from the trajectory obtained for the simplified one-valued system without a discontinuity and for the still more simplified system with a discontinuity at $x = 0$.

Using Liapunov's lemma on the stability of singular points of a nonlinear system investigated by means of a linearized system, the problem of existence, and that of the kind and of the stability of the singular points, is discussed. It was found that a double-

valued system in the environment of $x = 0$ gives a result conforming to experience (with dry friction, total extinction of free vibrations appears after a finite number of oscillations, even at arbitrarily small amplitudes). A simplified one-valued scheme of friction does not agree with experience because the vibration tends to zero and does not die out completely after a finite number of periods. J. Naleszkiewicz, Poland

1986. Rivals, J.-L., Balancing of oscillating masses in ballistics (in French), *Mem. Artill. fr.* **31**, 121, 627-692, 1957.

Paper deals with balancing problems in artillery guns. After some simple examples the details of spring and pneumatic stabilizers are worked out. A new method is given to establish the characteristics of a stabilizer which approaches the perfect stabilizer. In order to facilitate the work, several tables of the functions used are included.

From author's summary by M. Rand, Canada

1987. Huffington, N. J., Jr., and Hoppmann, W. H., II, On the transverse vibrations of rectangular orthotropic plates, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-85, 7 pp.

Frequency equations and modal eigenfunctions are determined for the flexural vibrations of rectangular plates of orthotropic material having two parallel edges simply supported and six different combinations of simply supported, fixed or free edges on the other two edges. The deflection of the plate is represented by a sine series expansion according to M. Lévy.

In addition, an orthogonality criterion for the eigenfunctions is established for a broader class of rectangular plates, having two parallel edges elastically supported, and relations for the kinetic and potential energy are derived. Finally, paper shows the value of foregoing energy functions in the analysis of forced vibrations by Lagrange's method. C. Massonnet, Belgium

1988. Kaul, R. K., and Tewari, S. G., On the bounds of eigenvalues of a clamped plate in tension, *J. appl. Mech.* **25**, 1, 52-56, Mar. 1958.

Use is made of Temple's generalizations of Kato's theorem for the determination of close lower bounds to the fundamental frequency of vibration of a clamped square plate subjected to uniform biaxial edge tension. The result depends upon the solution of an auxiliary problem governing the residual mode shape, which is here obtained by the variational method of Ritz. The principle of the computation of the number ϵ_v^2 (which corresponds to the ratio of the elastic energies in the residual and the tentative mode) is explained, and the value of the lower bound is determined by using the inequality $(1 - \rho/\beta)(\rho/\alpha - 1) \leqslant \epsilon_v^2$. The results are compared with those obtained previously by Weinstein and Chien, and it is shown that the present method leads to much closer bounds.

From authors' summary by C. Massonnet, Belgium

1989. Mirsky, I., and Herrmann, G., Axially symmetric motions of thick cylindrical shells, *J. appl. Mech.* **25**, 1, 97-102, Mar. 1958.

An approximate theory of axially symmetric motions of thick, elastic, cylindrical shells, in which the effect of transverse normal stress is retained, is deduced by Hamilton's principle from the three-dimensional theory of elasticity; the displacement components of a point are approximated by the expressions

$$\bar{u}_x = u(x, t) + z\psi_x(x, t); \quad \bar{u}_z = w(x, t) + z\psi_z(x, t)$$

where u and w are the displacement components of a particle of the middle surface ($z = 0$), ψ_x is the angle of rotation of a cross section in the $x - z$ plane, and ψ_z is the transverse normal strain. This theory contains, in addition to the usual membrane and bending terms, the influence of rotatory inertia and transverse shear deformation.

As an example, the propagation of free harmonic waves in an infinite shell is studied both on the basis of the present theory and the three-dimensional theory of elasticity. Excellent agreement is obtained for the phase velocity of the lowest mode of motion for a wide range of the parameters involved.

From authors' summary by C. Massonnet, Belgium

1990. Toriumi, I., Vibrations in vicinity of foundations of machines, *Technol. Rep. Osaka Univ.* **6**, 103-114, Mar. 1956.

Surface waves under unidirectional excitation are described. The analytical solutions for the semi-infinite elastic solid are used to describe the displacements in the ground theoretically. Diagrams for the components of the horizontal displacements are given for three cases of compressor excitation. Tests with an electrically driven oscillator are described, the distribution of the amplitudes of ground oscillation for different directions shown. An example for vibrations of wooden houses is cited.

No reference to experimental or analytical work of other authors in the field is given. A. Slibar, Germany

1991. Polz, K., Vibrating twin block foundation with elastic intermediary layer (in German), *Bautechnik* **34**, 1, 20-23, Jan. 1957.

If a pulsating force acts on the upper block of the foundation, elastic displacement $\eta = r^{-1}f(at - r)$ spreads in the soil (r wave radius, t time, a propagation speed). Stresses in the soil and in the intermediary layer and pressures over the base can then be derived from η.

The deflection of the base is denoted by $\eta_0 = b^{-1}f(at - b) = b^{-1}f(z)$. Having written for each of the blocks the equation of motion, substitution leads to a single fourth-order differential equation of function $f(z)$ with constant coefficients, depending upon inertia of the blocks, elasticity of layer and soil, and value of speed a.

Solution is given in the form $f = \int_{-b}^{z} F(\xi)\, g\,(z - \xi)d\xi$ in which F is the disturbing action and g is a Green's function of time interval $(z - \xi)/a$, the integral being extended from origin of time up to present value z.

Through well-suited high-level developments, author derives expression of displacements and stresses due to a periodic pulsating force or to a single impulse.

In the first case, harmonic functions are obtained having the same frequency of the disturbing force and different phase; in the second problem, F is assumed to be constant during a very short interval r; no integration is required, being $f(z) = Fg(z - z_0)ar$. In this case amplitudes of stresses and deflections for a given r decrease with time through an exponential factor.

If the impulse is given through impact, only the initial velocity of the upper block needs to be known to derive function η.

Different forms of disturbing actions are exemplified: vertical force, (bending) couple in vertical plane, (twisting) couple in the horizontal plane.

The case of single-block foundation with elastic layer leads instead to a third-order differential equation.

Method is applied to the study of an engine foundation consisting of a plate resting by mean of six columns on a second block which, when in use, showed exceptional torsional vibrations.

Calculated resonance frequency was in very good agreement with actual one; magnification factor of the stresses in the columns was found to strongly depend on the characteristics of soil, this last fact being neglected in usual specifications.

Not infrequent printing mistakes can be easily corrected by the reader. D. Gentiloni-Silverj, Italy

1992. Ioanide, P., The question of the critical running speed of gas turbine prime movers (in Russian), *Trudi MAI* **38**, 68-92, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6939.

An investigation of the small free and constrained vibrations of a disk fitted on an elastic rotating shaft.

Neglecting the shaft mass, author obtains a system with four degrees of freedom, for which a Lagrange equation of the second type is derived. Integration of the consequent linear system of four equations leads to the equations of the frequencies. It is suggested that in the general case, these frequency equations be solved graphically. Resonance cases are investigated.

G. N. Bukharinov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1993. Kuznetsov, V. S., and Lysenko, B. M., The influence of elasticity of the attachment on the natural frequency of vibration of turbine blades (in Russian), *Sb. nauk Labor. problem Cystrokhod. mashin i mekhanizmov Akad. Nauk USSR* no. 5, 179–186, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7787.

The factors are examined which influence the coefficient of reduction of the frequency φ, representing the ratio between the actual frequency of vibration of a cantilever bar to the theoretical frequency.

On the basis of experimental investigations, in which the deformations in the rigidly-gripped end of a cantilever bar were measured, and of approximate analytical calculations, the allegation is disposed of that the criterion of the reduction in frequency, due to the elasticity of the attachment, is the flexibility of the bar, l/ρ: experiments have shown that φ depends on the ratio of the square of the length of the bar l to the radius of inertia ρ of its cross section.

G. S. Pisarenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

1994. Traill-Nash, R. W., On the excitation of pure natural modes in aircraft resonance testing, *Aero. Res. Lab. Melbourne, Austral.*, SM 254, 12 pp., July 1957.

A technique is indicated for exciting a pure undamped mode of a structure by means of distributed excitors.

The method consists of recording the m-place displacements at a number of stations, at least one less than the effective number of the degrees of freedom, n, which are excited by n shakers producing linearly independent force distribution at the undamped frequency of the mode to be measured. Pure mode response is obtained by a systematic adjustment of force amplitude. In order to start the process the undamped frequency should be known to a higher degree of accuracy, although it is claimed that successive adjustments of the force distribution can be used for improving the initial frequency estimate.

Paper is theoretical and no indication of actual test results is given.

M. V. Barton, USA

1995. Clarkson, B. L., Stresses produced in aircraft structures by jet efflux, *J. roy. aero. Soc.* **61,** 554, 110–112, Feb. 1957.

The sound pressures associated with a jet efflux set up stresses in an aircraft structure which are essentially those occurring in the resonant condition of the structure. These stresses are of low magnitude by static standards but, because of their high frequencies, are dangerous for fatigue.

Author has proposed a simplified method by which the rms value of the stress envelope in any aircraft structure situated in the rear field region of a jet efflux may be approximated. This is done by assuming vibrations to be local vibrations of skin panels and stringer having no spatial phase, or pressure, change in each frequency component over the small area involved. A damping value must also be assumed. The de Havilland Comet aircraft is used as a specific example.

Strain-gage measurements show that there is essentially a random phase relationship between pressure components at a given frequency at different positions on the fuselage. This suggests the predominant form of vibrations to be local vibrations of components rather than vibrations of the structure as a whole. For a single-degree-of-freedom case (panel vibrating in its first natural mode at frequency ω_0 and with a proportion of critical damping) the panel will only respond to pressure components in the range of $\omega_0 \pm \delta\omega_0$. If the several frequencies which contribute to the final response have a random phase relationship, the square value of the stress envelope is given by $\zeta^2 = \frac{\pi}{4\delta}\ \omega_0 P(\omega_0)\ s_0^2$ where $P(\omega_0)$ is the power spectral density of pressure at frequency ω_0, s_0 is the static stress per unit imput pressure, and the other terms are as defined above. Author obtains mean square value of the stress envelope for first and second modes, then adds to obtain the mean square value for the total response. Estimates obtained are of the same order of magnitude as measured values for the Comet fuselage.

E. L. Foster, USA

1996. Mead, D. J., The effect of structural damping upon the stresses due to jet efflux, *J. roy. aero. Soc.* **61,** 554, 108–109, Feb. 1957.

Since the noise spectrum for jet engine efflux is essentially "white," it is impossible to "tune" a structure to avoid resonance of the airframe structure. Under these conditions, vibration in each mode of the structure will occur at or near the natural frequency and damping will be the most important factor in determining the amplitude in each mode.

Damping derives from three sources: (1) structural hysteresis originating at riveted or bolted joints, (2) acoustics damping from sound energy radiated away by vibrating surfaces, and (3) friction introduced by soundproofing, internal furnishings, stored equipment, etc. An efficient increase is conceivable only for structural damping.

Damping forces at riveted joints arise from the fact that a well-formed rivet exerts an internal pressure on its hole together with a normal pressure between the riveted plates. There are resulting frictional forces which resist relative motion of the plates. These forces must be overcome before the rivet takes appreciable load. Thereafter, the rivet deflects and there is relative motion between the plates.

Damping forces at riveted joints arise when the rivet deforms allowing relative motion between the plates. Damping occurs as energy is dissipated in the motion. Preliminary work on single joints has shown these forces to be nonlinear. Greater rivet slip should produce greater damping. However, this will reduce structural rigidity and may increase the damper from fretting and fatigue. It has been shown that the addition of a thin layer of certain compounds between joint plates will increase damping by several times. Author believes structural damping may be increased by a factor of 10 or more by the use of inserts. This could significantly decrease both the displacements and stress amplitudes.

A program is underway at the University of So. Hampton to investigate the relative magnitudes of the sources of damping. This will lead to a test of a model fuselage having frames, stringers, and joints.

E. L. Foster, USA

1997. Fehrle, L., Critical speed of certain motor forms with consideration of gyratory effects. II Contribution (in German), *Ing.-Arch.* **25,** 5, 319–329, July 1957.

Following up results of an earlier paper [AMR **10,**(1957), Rev. 1351], author gives details of example where approximate methods of Ritz' and Grammel's type may be compared with exact solution. This is the case of a simply supported rotor with constant flexural rigidity and its mass and gyroscopic action uniformly distributed along one half of its length. The cases of synchronous precession in directions equal and opposite to that of rotation lead to virtually the same transcendental equation for the eigenvalues. The two lowest eigenvalues are tabulated with or without taking account

of gyroscopic action. Results show certain preference for the Grammel type of approximation, particularly for the second eigenvalue. F. K. G. Odqvist, Sweden

1998. Will, B., The coefficient of cyclic variation of diesel electrical units under consideration of the shaft elasticity. Parts I, II, *Forsch. Geb. Ing.-Wes.* **22,** 5, 197–201, 1956; **22,** 6, 167–177, 1956.

The coefficient of cyclic variation is defined by $\delta = (n_{max} - n_{min})/n$ when n_{max}, n_{min}, and n designate the maximum, minimum, and average number of revolutions per minute. In order to calculate δ, one usually makes the assumption of a rigid shaft, which is inaccurate if n is near a resonance frequency of the shaft.

The present paper discusses very thoroughly in part I the changes which are necessary in the calculation if the shaft performs torsional vibrations. Particular attention is given to Diesel units, for which special cases are discussed in detail and an auxiliary function is tabulated, facilitating numerical calculations. In part II, two examples illustrate the method in great detail; comparison with results for the rigid shaft and with actual measurements is made. H. L. Oestreicher, USA

1999. Perzhnyanko, E. A., Vertical vibrations of a body floating on the surface of a liquid between two parallel walls, and waves resulting from them (in Russian), *Prikl. Mat. Mekh.* **20,** 3, 362–372, May-June 1956.

Writer extends work of L. N. Sretenskii to more complicated boundary, rendering a rather complete analysis (11 pages). Resonance of body and resonance of waves are two different things: considering forced vibration, body offers most resistance to motion when waves are at resonance. Effect is similar to that of a "dynamic absorber." R. A. Burton, USA

Wave Motion in Solids, Impact

(See Rev. 1854)

Elasticity Theory

(See also Revs. 1878, 1998, 2048, 2049, 2055, 2056, 2057, 2063, 2077, 2079, 2108)

Book—2000. Houwink, R., Elasticity, plasticity and structure of matter, 2nd ed., Washington, D. C., Harren Press, 1953, xviii + 368 pp. $2.98. (Paperbound)

Book is a new edition of Houwink's 1937 treatise on the properties of elastic and plastic solids. The style is that of clear and detailed description, with many figures and illustrations and only the necessary mathematics.

The first chapters discuss elastic and plastic flow properties and their interpretation in terms of the physical structure of matter. Then combined elastic and plastic behavior, plastic deformation of crystals by slip propagation, etc., are covered.

The general chapters are followed by detailed studies of the fundamental properties of glass, resins, asphalt, rubber, guttapercha, balata, cellulose, starch, proteins, dough, paints, lacquers, clay, and sulfur, particularly their mechanical structure and elastic and plastic behavior. C. F. Bonilla, USA

2001. Rogozinski, M., A tentative establishment of theoretical foundations of the moire method of analysis of strain and stress (in English), *Arch. Mech. stos.* **9,** 2, 191–210, 1957.

Application of rasters of equal-sided triangles or regular hexahedrons is considered. It enables the determination of strain components, elongation, and the angle of distortion. The author discusses conditions for using the above method for examining the deformation of nonhomogeneous nonisotropic bodies. The paper does not contain any example of application of the method discussed. J. Mossakowski, Poland

2002. Marciniak, Z., Graphical representation of the state of stress and strain (in English), *Arch. Mech. stos.* **9,** 2, 261–274, 1957.

Author proposes a representation of the state of stress and strain at a point by means of graphical constructions giving a plane image of these states.

The idea of representing the state of strain and stress on a plane is, of course, not new. Geometrical properties of a triangular system were already used for the representation of states of strain and stress, among others by T. Pelczynski. The present author introduces a triangular system by projecting the Cartesian system on the octahedral plane.

In no other paper are the properties of the triangular system given to such an extent. Many very simple and useful results are obtained. To these belong graphical determination of the value of strain intensity, distortion energy, effective stress strength diagrams, etc. S. Ziemba, Poland

2003. Duffin, R. J., Analytic continuation in elasticity, *J. rational Mech. Analysis* **5,** 6, 939–950, Rev. 1956.

2004. Kuranishi, M., The finite natural strain consisting of the logarithmic and the angular strain, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 17–22.

Author defines a strain-like complex consisting of (1) the integral sum of the current infinitesimal extensional rates of an element, and (2) the integral sum of the infinitesimal angular change of the current principal axes. For elements in the direction of the principal axes, his first expression leads to the "natural" (or Hencky) strain measure. It must, however, be pointed out that this complex does not constitute a tensor. The tensor for this measure has been derived by Hanin and Reiner [AMR **10,** Rev. 1308]. In order to express the stress, author introduces certain terms taking account of the rotation of the element. He then treats "simple shear", "simple slips", and combinations of these. M. Reiner, Israel

2005. Hicks, R., Reinforced elliptical holes in stressed plates, *J. roy. aero. Soc.* **61,** 562, 688–693, Oct. 1957.

Paper considers problem of a reinforced elliptical hole in a plate under the action of a principal stress system of the type found in cylindrical and ellipsoidal pressure vessels, that is, stress system in which the ratio of the principal stresses is not greater than two to one. It is shown that, when the ratio of the major and minor axes of the ellipse can be chosen arbitrarily, practical reinforcements can be designed to give a maximum stress around the hole which is only slightly greater than maximum stress in a similar plate with no hole. General expressions are obtained for the stress distribution.

From author's summary by H. Fernandez Long, Argentina

2006. Hioke, M., The interpretation of defined two-dimensional inherent stress conditions as membrane stresses (in German), *ZAMM* **37,** 5/6, 177–191, May/June 1957.

In two-dimensional strain problems, not satisfying the compatibility conditions it is, in some cases, possible to state how the surface elements may be fitted together, without applying any stress, by treating the plate as a membrane, and curving it in a suitable way. In this fashion are treated the thermal deformation of a membrane bounded by two eccentric circles (a constant temperature distribution is imposed along the circles); a circular membrane with a heat source at its interior, a cylindrical shell with axial temperature variations. In some cases the knowledge

of the surface area which is being deformed without any stress proves to be of advantage in determining the initial stresses (Eigenspannungen) due to impeded bulging.

G. Sonntag, Germany

2007. Koppe, E., The thick plate with nonlinear stress distribution (in German), *ZAMM* **37,** 1/2, 38–44, Jan./Feb. 1957.

A general and rather convenient method of finding an exact solution of a problem of thick plates with nonlinear stress distribution is demonstrated on a specific example. The invariants of the problem are used as a starting point in this method. The lateral boundary of a plate may be subjected to any combination of independent-one-from-another normal tangential and shear forces, and bending and twisting moments. The displacement distribution functions are found for two practically important and quite general systems of loads.

From author's summary by R. M. Evan-Iwanowski, USA

2008. Yamaki, N., Stress distribution in a rectangular plate under a pair of concentrated forces, *Rep. Inst. high Speed Mech. Tohôku Univ.* **8,** 1–12, 1957.

Author presents solution in infinite series form for stress distribution in rectangular flat plate (plane strain) subjected to equal opposing concentrated loads applied at the mid-point of two opposite sides of rectangle. Numerical values are presented for several cases for which photoelastic data are available. Results compare favorably. In addition, experimental results using strain gages are given and compared with corresponding results predicted by theory. Agreement is good. H. J. Plass, Jr., USA

2009. Rvachev, V. L., Pressure on the elastic half-space under a die having the surface of contact in the form of a strip (in Russian), *Prikl. Mat. Mekh.* **20,** 2, 248–254, Mar.-Apr. 1956.

The integral equation for pressures on the surface of an elastic half-space under the influence of a die can be solved by means of an auxiliary function satisfying Poisson's equation, if the die surface can be written in the form $u(x,y) = f(\lambda,x)\cdot\cos\lambda y$. Using elliptic coordinates and taking the solution of the equation in the form of a product, Mathieu's equations are obtained for both factors. After mentioning some properties of Mathieu's functions, author derives the equation for the auxiliary function, if $f(\lambda,x)$ can be decomposed in a series of Chebyshev's polynomials which is uniformly convergent in the whole interval $-a \leqq x \leqq a$. Numerical results are given for $f(\lambda,x) = \text{const}$, and, after some considerations on the asymptotic behavior of the auxiliary function, paper is closed by a few remarks on the convergence of the integral expression for pressure. A. Kuhelj, Yugoslavia

2010. Pacelli, M., Contact with friction between two elastic borders of arbitrary shape: Compression and torsion (in Italian), *Ann. Scu. norm. sup. Pisa* **10,** 3, 155–184, 1956.

Author completes and generalizes recent works of Mindlin, Lubkin, and Cattaneo concerning the determination of the couple of resistance in the relative rotation of two rigid bodies in contact. It is assumed that the bodies are homogeneous and isotropic and that the tangent force is finite and continuous with the surface of contact σ which, as Hertz proved, is an ellipse.

The friction at point A_* of the ellipse σ_* ($\sigma_* \leqq \sigma$) is perpendicular to the radius and is denoted by $r_*(l_*, m_*)$.

In §§ 2,3, author finds again with some addition the approximate solutions of Cattaneo in two cases, the partial of the two spheres and the general one.

In § 4 he finds the forms

$$l_*^{(n)} - l_r^{(n)} = l_r^{(n)}\,\varphi^{(n)}(\lambda,\mu_*),$$
$$m_*^{(n)} - m_r^{(n)} = m_r^{(n)}\,\varphi^{(n)}(\lambda,\mu_*),$$
$$\omega = Gb^{(n)}(\lambda),$$

where λ, μ are the constants of Lamé. In the general case it is

$$\lambda = \frac{\alpha_*}{\alpha}\frac{\beta_*}{\beta}, \quad \mu_* = \left(1 - \frac{\chi^2}{\alpha_*^2}\frac{M^2}{\beta_*^2}\right)^{\frac{1}{2}}, \quad G = -\frac{3fP}{4\pi b\beta}.$$

Then the expressions of the second sides of the above forms are found, and the way in which the solutions come out with a corresponding approximation is demonstrated.

In § 5 it is shown how the determination of the distribution of the tangent forces is found from the above forms. This happens through a suitable transformation of Boussinesq-Cerruti's equations. Finally, author studies the properties of the functions in the second sides of the above types and checks their accuracy.

The work of Mauro Pacelli combined with the related works opens new ways of studying this difficult problem which calls for further research, from a theoretical point of view as well as in the practical applications. C. Papaioannou, Greece

2011. Paduart, A., Method of assimilation for the solution of two-dimensional elasticity problems (in French), *Ann. Trav. publics Belg.* no. 5, 53–74, 1956.

Using Airy stress functions, author derives solutions for normal and shearing stresses in infinitely long beams of constant height under plane stress for two types of loads: (1) equidistant concentrated forces normal to upper and lower beam face, acting alternatively; (2) equidistant concentrated forces tangential to upper and lower beam face, acting alternatively. Solutions are presented in tabular form.

Author also presents solutions for local stress concentrations near above forces and gives results in graphical form. For finite beam under concentrated loads, superposition of above cases gives stresses by iterative procedure in which internal stresses for infinite case are applied as external loads on infinite beam. This process is repeated until sufficiently good agreement is obtained. Example is given which indicates three successive approximations as adequate.

Method proposed is useful, in reviewer's opinion, in many practical cases where rigorous solutions are not available.

G. G. Meyerhof, Canada

2012. Vitkup, E. B., The displacements of points in an elastic semi-space under varying loading of its boundary surface (in Russian), *Trudi Kieosk. avtomob.-dor. in-ta* no. 2, 164–169, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6826.

The sinking of points in an elastic semispace under uniform loading of its boundary surface circularly and annularly is determined. The required displacements are expressed in the form of quadratures, which are calculated for points located under the center of the loaded circle or annulus. M. Ya. Leonov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2013. Chen, S. T., Analysis of beams on elastic foundations (in Chinese), *Chinese J. civ. Engng.* **3,** 3, 365–385, Aug. 1956.

Author modifies the method proposed by Zhmochken in solving problems of elastic beams supported on semi-infinite elastic media. In contrast to Zhmochken's cantilever beam, author uses a simply supported beam with cantilevers at both ends as the basic structure. Following the identical derivation as Zhmochken's, a set of numerical coefficients suitable for design purposes are given. A numerical example is worked out, in which iteration and successive approximation are used.

In an effort to simplify the solution to the simultaneous equations, author makes the assumption that the reactive forces between the beam and the elastic foundation are linearly varying. Reviewer believes that this can only be true when the beam is in-

finitely rigid as compared with the foundation and at points sufficiently away from concentrated loads and boundaries.

D. H. Cheng, USA

2014. Blackburn, W. S., Second-order effects in the flexure of isotropic incompressible elastic cylinders, *Proc. Camb. phil. Soc.* **53,** 4, 907–921, 1957.

Using complex variable notations, expressions for second-order stresses and displacements are obtained and evaluated for a circular cylinder loaded eccentrically in bending and in torsion.

W. Ornstein, USA

2015. Golecki, J., A sphere weakened by a concentric inclusion of different elastic properties under concentrated loads (in English), *Arch. Mech. stos.* **9,** 3, 301–317, 1957.

Solution is given for a sphere with a concentric spherical cavity compressed by two concentrated forces and for the same sphere with a concentric, perfectly rigid, spherical inclusion.

On the basis of Neuber's interpretation of concentrated diametral forces and of author's previous papers, expressions for strain and stress components are obtained by means of Legendre polynomials. The satisfaction of the boundary conditions reduces in the above cases to the solution of four algebraic equations with four unknowns. In the limit case, author derives the well-known solution for a full sphere. All the solutions are given in the form of uniformly covergent Legendre series. The paper is completed with stress diagrams in the case of $R_0/R = 0.25$, $\nu = 0.3$ and with tables enabling an approximate calculation of the series obtained.

J. Mossakowski, Poland

2016. Loo, T.-T., Effect of curvature on the Hertz theory for two circular cylinders in contact, *J. appl. Mech.* **25,** 1, 122–124, Mar. 1958.

Author makes use of the solution for the components of the displacement in an infinite circular cylinder, compressed along a chord of a section by a pair of equal, colinear forces, to compute the approach due to normal contact of two elastic cylindrical bodies.

H. Deresiewicz, USA

2017. Hetenyi, M., and McDonald, P. H., Jr., Contact stresses under combined pressure and twist, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-95, 6 pp.

Authors discuss the problem of two like, elastic spheres compressed by (constant) forces directed along the line of centers and subjected to additional forces statically equivalent to a couple about this line. The magnitude of the couple is assumed to be such as to cause incipient gross sliding at the contact. For this limiting case of combined pressure and twist, authors compute the distribution of stress. The two circumferential components of shearing stress are obtained in terms of infinite integrals, and turn out to be discontinuous at the center of contact, i.e., they approach a different limit along different paths.

Paper concludes with a description of photoelastic experiments on Fosterite in which the three-dimensional stress-freezing technique was employed. The results indicate good agreement with theoretical predictions.

H. Deresiewicz, USA

2018. Alexandrov, A. Ya., Some solutions of axially symmetrical contact problems in the theory of elasticity (in Russian), *Trudi Novosibir. in-ta inzb. sb.-d. transp.* no. 11, 20–61, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7667.

The application of a method of graphical analysis to the problem of axially symmetrical contact is described; the method was developed previously by the author for the two-dimensional case (cf. pp. 5–28 in the same issue)

The example of a rigid, conical punch in presence of friction with a coefficient $\mu = 0.1$ is examined.

N. A. Rostovtsev
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2019. Synge, J. L., and Cahill, W. F., The torsion of a hollow square, *Quart. appl. Math.* **15,** 3, 217–224, Oct. 1957.

The hypercircle method is used to determine stress function, warping function, and lower and upper bounds for torsional rigidity of a hollow square (studied earlier by Zachrisson, Proc. Eighth inter. Congr. appl. Mech., Istanbul, 1952, p. 136). A finite difference network is employed, with 48 subdivisions of outer boundary, to solve problem on SEAC computer. Stress function and warping function are given to three significant figures in triangulated octant, and torsional rigidity is also given to three significant figures.

J. Hult, Sweden

2020. Goulard, Madeline, Lo, H., and Bollard, R. J. H., Torsion with warping restraint of tapered beams, Proc. Third Midwestern Conf. on Solid Mech., Univ. of Mich., Apr. 1957, 100–112.

A cantilever, thin-walled tube of rectangular cross section in the shape of a truncated cone is subjected to a concentrated torque. Under the usual assumptions (especially the shape of the cross section is maintained by closely spaced rigid diaphragms) the distribution of twist and warping displacement is derived exactly using the theory of Hadji-Argyris and Dunne. But additionally, a variation calculus is used starting from Lagrange's function of the problem. This method leads to an approximate numerical calculus. The results for both methods are compared for a practical example.

H. Neuber, Germany

2021. Grossmann, G., Experimental realization of a new hydrodynamic analogy for torsional problems (in German), *Ing.-Arch.* **25,** 381–388, 1957.

Paper describes Pestel's hydrodynamic torsion analogy on the basis of equalization of differential equations for creeping flow and for Saint-Venant's torsion. Advantage of this analogy is the possibility of determining independently both the resistance and stresses of torsion in an easier way and with simpler equipment and analysis. Diagrams of experimental results are presented and their accuracy, satisfactory for technical purposes, emphasized. Comparative measurements on planes in accordance with Prandtl's analogy, which are required when, e.g., Reichenbächer's apparatus is used, are not necessary. Torsional resistance can be determined by measuring time and temperature, and the stress is in relation to the area between two lines of the flow. Results of model testing are applied to natural conditions by simple calculations, as demonstrated on examples.

Tests were performed in Materials Laboratory of Technical University in Hanover under the guidance of Prof. E. Pestel and E. Martyrer.

J. J. Polivka, USA

2022. Polozhyi, G. N., Some variationally topological theorems for the boundary problems of the torsional theory of shafts of variable cross section: A method of preservation of the region and the majorants (in Russian), *Izv. Akad. Nauk SSSR, Ser. Matem.* **19,** 3, 245–270, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6839.

The stress condition in the torsion of a shaft of variable cross section is determined by the complex stress potential

$$w = u(Z) = \varphi + i\psi$$

where $Z = r + iz$ ($ReZ > 0$), φ displacement function, and ψ stress function, related by the equations

$$\frac{\partial \varphi}{\partial r} = \frac{1}{\mu r} \frac{\partial \psi}{\partial z}, \quad \frac{\partial \varphi}{\partial z} = -\frac{1}{\mu r} \frac{\partial \psi}{\partial r}$$

The solution of the problem is thus reduced to finding the function w in the region G bounded by the discontinuously smooth contour L, in the plane $Z = r + iz$ ($ReZ > 0$) representing the axial section of the shaft, from particular contour conditions stated for the boundary L of the region G.

The variation of the complex stress potential is represented by a function of the complex variable:

$$w = u(Z) = w_1 - w = \sigma + ir$$

where $w_1 = \varphi_1 + i\psi$, = complex stress potential corresponding to the region G, obtained from G by such variation of its boundary that $G_1 \subset G$.

For stress regions bounded by two flow lines and two potential lines, analysis of the hodograph of the function w leads to setting up a group of theorems characterizing the variations in the presence of a constant torsional moment M of the summary angular rotation H, the function φ and the stress vector

$$v = r_{r\theta} + ir_{z\theta} = \mu r \nabla\varphi = -\frac{i}{r^2}\nabla\psi$$

for (1) diminution of one of the limiting potential lines (i.e., the lines of $\varphi = \text{const}$); (2) inward bending of the bounding potential line; (3) inward bending of the bounding flow line (i.e., the line $\psi = \text{const}$). Theorems are stated for the same region with the same variation of the boundaries for a variation in the values of M, φ and v with a constant value of H.

Theorems of analogous kind are developed for regions bounded by two flow lines and one potential line and regions bounded by two flow lines, as well as regions containing in their boundaries lines of variable potential.

The theorems demonstrated are used by the author to support the Saint-Venant principle applied to the torsion of a cylindrical shaft with a lateral surface free from external forces, and for evaluating from below and from above the maximum shear stresses on the lateral surfaces of cylindrical shafts with annular grooves of hyperbolic and circular shape. For the first problem, the magnitude of the divergence of the stresses in the constrained cross section from a linear law, corresponding to the Coulomb solution, is stated; for the second, the maximum and minimum values of the magnitude of the maximum stresses are stated; these show fairly narrow limits for a small depth or a small width, of the groove.

K. V. Solyanik-Krassa

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

2023. Yakub, K., The torsion of cylindrical bars (in Russian). *Nauka v Rum. Nar. Resp.* no. 2, 5–13, 1953; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6843.

The problem is solved of the torsion of a bar the cross section of which is a circle, $|z| < R$, with n symmetrically placed internal radial notches. For $n = 1$ (notch $a < z < b$, $0 < a < b < R$), the stress function, as a solution of the equivalent Dirichlet problem for a plane with two notches, has the form

$$F(z) = \frac{i}{\pi}\sqrt{(Pz)}\int_a^b \frac{f(t)+c}{\sqrt{|P(t)|}}\left(\frac{1}{t-z}+\frac{t}{R^2-tz}\right)dt$$

$$\int_a^b \frac{f(t)+c}{\sqrt{|P(t)|}}\,dt = 0$$

where

$$P(z) = (z-a)(z-b)(z-R^2a^{-1})(z-R^2b^{-1})$$

$$\sqrt{P(z)} > 0 \text{ for } z = x > R^2a^{-1},\ f(t) = \frac{1}{2}(t^2 - R^2)$$

It must be mentioned that solution of problems of this kind by means of Cauchy-type integrals is well known [see N. I. Muskhelishvili: "Some fundamental problems of the mathematical theory of elasticity," 1954, para. 120; L. I. Sedov, *Uspekhi matem. nauk*, no. 6, 149–155, 1939]. For any value of n, the problem can be reduced to the preceding form with the help of the transformation $Z = z^n$. Solutions are also given for the problems of bar torsion, in which the cross section is a circle with symmetrically arranged radial notches issuing from the boundary, the circle $|z| \leqslant R$ with two notches, $-R \leqslant z < -a$, $b < z \leqslant R$.

P. P. Kufarev

Courtesy Referativnyi Zhurnal, USSR

Translation, courtesy Ministry of Supply, England

2024. Green, A. E., Radok, J. R. M., and Rivlin, R. S., Thermoelastic similarity laws, *Quart. appl. Math.* **15,** 4, 381–393, Jan. 1958.

Authors show that a constant ratio of the stresses in the body to those in the model equal to the ratio of the moduli of rigidity exists provided certain relations among the physical parameters are the same for the model and the body. In the general case the three relations (1) Poisson's ratio m, (2) AT_0, (3) kt_0/Dc_pL^2 must be the same in model and body, where A is coefficient of linear thermal expansion, T_0 constant temperature ratio between body and model ($T_0 = 1$ for model), k thermal conductivity coefficient, D density, c_p specific heat, t_0 constant time ratio between body and model, L constant dimension ratio between body and model ($t_0 = 1$, $L = 1$ for model). For the plane strain problem, relations (1) and (2) reduce to one relation $AT_0(1 + m)(1 - m)$. It may be noted that this latter relation together with relation (3) are the basic parameters arising in much of the work on thermal stresses in plates (see, for example, p. 67–83 in Gatewood, "Thermal stresses", McGraw-Hill Book Co., New York).

B. E. Gatewood, USA

2025. Baehr, H. D., Nonstationary thermal stresses in composite brick-metal containers and the computation of wall thicknesses with help of a temperature graph (in German), *Ing.-Arch.* **25,** 5, 330–349, July 1957.

In chemical engineering, steel containers are often protected by brick layers to prevent corrosion. An analysis is given for the design of these vessels which are usually subjected to varying temperatures and pressures. Conditions for satisfactory operation are (a) brickwall not detached from metal container, (b) absence of mechanical tensions in brick wall, and (c) loads in the metal container to remain within permissible limits. To fulfill conditions (a) and (b) the brick wall is prestressed by using an expanding cement between wall and metal container. Thorough analysis covers calculation of the initial stresses, design of wall thicknesses under steady-state and transient temperature distributions. Of these, the latter are, in most cases, the more important. Two examples illustrate practical applications.

Paper should be important for all engaged in design of this type of equipment.

H. Schuh, Sweden

2026. McDowell, E. L., Thermal stresses in an infinite plate of arbitrary thickness, Proc. Third Midwestern Conf. on Solid Mech., Univ. of Mich., Apr. 1957, pp. 72–85.

The problem is reduced to the determination of the solution fields of an analogous half-space problem. First a particular (singular) solution is established of the thermoelastic field equations appropriate to a surface point-source of temperature and then, in analogy to the method of Green in potential theory, an integration over the boundary leads to the solution (presented in series) for an arbitrary distribution of surface temperature.

From author's summary by G. Sonntag, Germany

2027. Sharma, B. D., Stresses due to a nucleus of thermoelastic strain (I) in an infinite elastic solid with spherical cavity and (II) in a solid elastic sphere, *ZAMP* **8,** 2, 142–150, 1957.

The solution of the thermal stress problem in an infinite elastic solid with a localized heated region (J. N. Goodier) is known. A spherical cavity is introduced in the solid with the heated region a finite distance from it. The displacements and stresses at the surface of the cavity are obtained in the form of a series solution superposed on the infinite solid solution. This is done by the introduction of a pair of exterior, spherical harmonics of integral order as stress functions. The boundary values are set by the condition that the cavity is free from traction, i.e., the radial stress and shears are zero at the surface of the cavity. The solution is presented in formulas in series form. A numerical solution is given in the text. The solution for deflections and stresses at the surface of a solid elastic sphere with a localized heated region was obtained in a similar manner. A numerical example is given. E. G. Allen, USA

2028. Nowacki, W., A three-dimensional thermoelastic problem with discontinuous boundary conditions (in English), *Arch. Mech. stos.* **9**, 3, 319–324, 1957.

An elastic semispace limited by the plane $z = 0$ is subjected to a temperature $T = \text{const}$ on the circle $r \leq a$; in the region $r \geq a$, the condition $\partial T/\partial z = 0$ is satisfied. The problem of steady-state temperature distribution is considered. The temperature distribution is given for the boundary conditions thus established. A particular integral of the thermoelastic potential equation is determined. In order to satisfy the boundary conditions, Love's stress function is introduced. Expressions for stresses σ_{zz} and σ_{yy} are given. It is shown that $\sigma_{xz} = \sigma_{yz} = 0$.

J. Mossakowski, Poland

2029. Nowakowski, W., A dynamical problem of thermoelasticity (in English), *Arch. Mech. stos.* **9**, 2, 325–334, 1957.

The state of stress in an elastic space in considered, due to a concentrated source of heat constituting a function of time $f(t)$. Three cases are discussed in particular, where $f(t)$ is assumed to be the Dirac impulse, the Heaviside unit function, and a harmonic function. In the basic equilibrium equations the influence of the inertia forces is considered, causing spherical elastic waves in the space.

Solutions, obtained by means of Laplace and Fourier transformation, are presented in closed form.

M. Sokolowski, Poland

2030. Nowinski, J., The principle of stationary free energy in the thermoelastic analysis of thin-walled tubes (in English), *Arch. Mech. stos.* **9**, 2, 359–369, 1957.

Basic equations of the theory of thin-walled tubes with open cross sections are derived using the principles of thermoelasticity.

For this purpose, author uses the principle of minimum free energy established by W. S. Hemp. A simple variational process leads to differential equations for displacements.

All auxiliary values appearing in the paper are also determined.

The results presented are valuable generalizations of the theory of thin-walled tubes created by W. Z. Wlasow and by the author in other of his papers. T. Iwinski, Poland

Experimental Stress Analysis

2031. Leven, M. M., and Wahl, A. M., Three-dimensional photoelasticity and its application in machine design, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-87, 9 pp.

The simplest equipment, the best model materials, and the most effective techniques for three-dimensional photoelastic tests are described. The optical equipment involves only a simple diffusion polariscope using only a single camera lens. Phthalic anhydride-cured epoxy resins, which are relatively easy to cast in large sizes, have much superior properties for photoelastic tests than previously used materials. A simple technique of using surface slices and normal incidence of light will give adequate results for the stresses on free surfaces. At interior points, the effective stress can be obtained by measuring the retardation and isoclinic parameters on the three faces of random oriented small cubes. Some discussion is given regarding methods of applying the photoelastic results in practical design applications where fatigue, repeated strain cycling, plastic flow, and creep-rupture effects may occur during operation.

From authors' summary

2032. Fessler, H., and Rose, R. T., Photo-elastic investigation of stresses in the heads of thick pressure-vessels, Instn. mech. Engrs., Prepr., 13 pp., June 1956.

The frozen-stress photoelastic technique is used to study the stresses in four different shapes of full drumheads and in five drumheads with circular or elliptical manholes. Circumferential and meridional stresses on inside and outside surfaces are presented, and some of these are compared with stresses calculated from different thin-shell theories. These theories were modified to be more realistic for thick shells by considering the pressure to act on the inside instead of the middle surface of the shell. The wall thickness of every drum was one-tenth of the mean diameter of the drum.

The effect of large elastic strains was studied by means of two identical models tested at different pressures. Calculations showed that the stresses were slightly decreased when Poisson's ratio was changed from ½ to ¼. The effect of a reduction of the wall thickness of hemispherical heads was calculated and was found to be in good agreement with experimental results. The stress distribution in the walls of the shells was also determined for some critical sections. From authors' summary

2033. Udoguchi, T., and Kunio, T., Photoelastic stress analysis for axisymmetrical problems. 2. Another method complemented with scattered light method, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 131–135.

Another simple method for the analysis of axisymmetrical stress by using parallel polarized light together with scattered light is proposed. The parallel polarized light is used for determination of stresses in the plane which contains the axis of symmetry, and the scattered light for a principal stress acting normally to this plane. As an illustration, the problem of an elastic sphere under diamentral compression is again taken up, and the results are compared with the theory. From authors' summary

2034. Fessler, H., and Ollerton, E., Contact stresses in toroids under radial loads, *Brit. J. appl. Phys.* **8**, 10, 387–393, Oct. 1957.

Authors have made an extensive series of measurements on pairs of Araldite plastic bodies pressed together under normal loads. They employed pairs of specimens with a variety of combinations of barrel-shaped, saddle-shaped, spherical, cylindrical and plane surfaces. Surfaces with both principal curvatures negative (bowl shaped) were not included. In addition to measurements of the elliptic shape of the contact surface, the photoelastic freezing and slicing technique was used to measure the magnitude and position of the maximum shearing stress (along the axis of the load) and shearing stresses in the planes containing the axis of the load, and the principal axes of the ellipse of contact. The latter stresses reverse sign during polling and their maximum range can exceed the maximum shearing stress if the principal axis of the ellipse of contact in the direction of rolling is sufficiently longer than the other principal axis. All of the experimental results are plotted in concise dimensionless form, and are shown to compare favorably over a wide range with the results of equally extensive computations from the Hertz theory.

R. D. Mindlin, USA

2035. Crisp, J. D. C., The measurement of plane strains by a photo-screen method, *Proc. Soc. exp. Stress Anal.* **15,** 1, 65–76, 1957.

Light passed through two sets of uniformly spaced lines causes a fringe pattern to be formed because of a periodic mechanical blocking of the light. This will occur unless the two sets of lines are identical both in spacing and direction. This principle has been applied for the measurement of large strains (greater than 1%). Convenient charts have been made whereby the strain can be directly determined if the line spacing of the master screen, and of the angle between the fringe direction and the master screen lines, is known. The technique requires a transparent test model on which a model screen is formed from the master screen by a photographic process. The strain sensitivity is shown to be a function of the gage length and of the number of lines per inch.

For a gage length of 1 inch, the least measurable strain is about 1% for 100 lines/inch, and about 0.2% for 500 lines/inch. An interferometer suitable for this type of strain measurement is described.

I. Vigness, USA

2036. Pindera, J. T., Application of the method of brittle coatings in the investigation of deformation type and regions (in Polish), *Rozprawy Inz.* **5,** 1, 33–48, 1957.

A method of brittle coatings for the determination of deformation of plastic metals is described. This method is based on the phenomenon of cohesion loss between the coating and the metal if plastic deformations appear. Various observation methods of deformations are compared. Plastic deformations in test pieces during tension and bending test are illustrated with photographs. Experimental results are compared to theoretical solutions.

T. Rajfert, Poland

2037. Suddarth, S. K., A transformer-type strain gage for wood, *Forest Prod. J.* **8,** 2, 79–81, Feb. 1958.

The use is described of a linear variable differential transformer as a displacement gage for measuring strain in wood members. A gage length of 4 in. is considered a practical minimum for measuring stresses in wood amounting to at least 100° psi.

E. G. Stern, USA

2038. Miller, M., Mantel, E., and Coleman, W., An evaluation of the x-ray diffraction method of stress measurement with a comparison to dissection methods of residual stress measurement in hardened steel, *Proc. Soc. exp. Stress. Anal.* **25,** 1, 101–112, 1957.

Recent developments in the field of x-ray diffraction measurement of strain in metals have led to renewed interest in its use in the determination of residual stresses. An investigation was undertaken to determine the degree of accuracy obtainable in measurement of applied mechanical stress or strain and residual or internal stress in hardened steel. A simple fixture was utilized to apply a mechanical strain to a specimen which was then measured both by x-ray diffraction (Christenson and Rowland technique) and electric resistance strain gages. This indicated a mean deviation of ± 5000 psi. Additional data is presented on the effects on stress measurements of certain geometrical factors of the x-ray equipment, such as apecimen displacement from the center of Geiger counter rotation, etc. A direct comparison with residual stress results obtained by dissection methods is made on carburized blocks. Additional results include gear and bar specimens. The conclusion is reached that residual stresses can now be measured in hardened steel to an accuracy which is comparable to mechanical methods. In applications where surface values of residual stress are sought, the x-ray method has a distinct advantage over mechanical methods.

From authors' summary

Rods, Beams, Cables, Machine Elements

(See also Revs. 1913, 1916, 1917, 1918, 2013, 2014, 2020, 2022, 2023, 2099, 2113, 2150)

2039. Minakov, A. P., Reaction effect of variation in the length of the ballooning section of a thread on its tension during axial unwinding from the surface of revolution (in Russian), *Naucb.-issled. tr. Mosk. tekstil'n. in-ta* **15,** 5–16, 1955; *Ref. Zb. Mekh.* no. 10, 1956, Rev. 6383.

Examination of the process of axial unwinding of a thread from the surface of revolution having regard to the variation in length of the ballooning section of the thread. A detailed examination of the kinematics of unwinding is made, and formulas are obtained which give expressions for the angular velocity of the ballooning, the velocity of the points of the thread, etc., dependent upon the direction of the motion of the point of removal of the thread in the direction of unwinding or toward it.

Methods of dynamics of the point of variable mass are used for determining the tension of the thread, arising as a result of the reactive force. The reactive component of tension may have a value of the order of tens of grams.

A method of winding is suggested in which the reactive force is equal to zero.

A. S. Petrov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2040. Davidsson, W., Investigation and calculation of the remaining tensile strength in wire ropes with broken wires (in English), *IngenVetenskAkad., Stockholm* no. 214, 38 pp., 1955.

The remaining tensile strength P_{ds}, as estimated by static tensile test of a straight rope, is not adequate to serve as a starting point for judging whether a rope should be discarded or not. In this respect the remaining bending tensile strength P_{bdr} which is obtained by bending the rope over a pulley when in movement and under a load should be decisive. For ropes with two layers of wires in the strands, covered by the investigation, $P_{bdr}/P_{ds} \approx 0.78$ may be set in the case of moderate weakening owing to wire breaks and wear.

The wire recovery length has been investigated in static remaining tensile strength tests. Here, among other things, it proved that the wire recovery length is not equally great for the different layers of wire in the strands. Thus for ropes with two layers of wires in the strands the wire recovery length in the inner layer was only about half that of the outer one.

A method is given for calculating the weakening due to wire breaks and wear of the tensile strength of a rope which is still in use.

Some fifty discarded crane, lift and telpher ropes have been investigated with regard to the occurrence and distribution of invisible wire breaks.

Finally, the advisability of choosing the rope lay as the control length is pointed out.

From author's summary

2041. Efsen, A., Spiral socket splices for deformed bars (in Danish), *Bygnsstat. Medd.* **28,** 1, 1–13, Oct. 1957.

Paper deals with a special overlapping splice for deformed reinforced-concrete bars. The splice is named a spiral (socket) splice as the outstanding feature is a spiral around the splice proper.

It is a logical solution for a splice where the concrete is to be the medium to carry the stresses from steel rod to steel rod; generally because the design has a symmetrical character, and specially because the play of forces in a well-defined way takes place in a very confined part of the concrete, i.e. in the space inside the spiral.

From author's summary

2042. Jain, B. K., Unsymmetrical bending and bending combined with thrust in unsymmetrical sections, *J. Instn. Engrs. India* **37,** 6, part 1, 585–612, Feb. 1957.

Paper attempts to present the subject of unsymmetrical bending in a more or less comprehensive form, starting from basic principles. It also deals with cases of bending combined with thrust in short columns of symmetrical and unsymmetrical sections.

From author's summary

2043. Piszczek, K., The influence of the curvature of an originally curved bar on the resonance regions of plane form of bending (in English), *Arch. Mech. stos.* **9**, 2, 155–190, 1957.

For a bar of natural continuous original curvature, loaded at the ends with a pulsating moment $M(t) = M_0 + M_1 \cos t$, simultaneous flexural and torsional vibration is considered in the case of hinged and clamped ends. In both cases the problem reduces to the investigation of the stability of the solutions of Mathieu's matrix equation. Starting from M. G. Kreyn's considerations and Hill's solution, boundary curves of the fundamental resonance regions are determined in an approximate manner. The influence of the original curvature and of the way of end support on the resonance regions is illustrated by a numerical example. From the example it follows that one of the two fundamental resonance regions is most narrow for values of the parameters of the system such that, for the statical load ($M_1 = 0$), no coupled vibration occurs.

M. Piatek, Poland

2044. Kaar, P. H., Stresses in centrally loaded deep beams, *Proc. Soc. exp. Stress. Anal.* **15**, 1, 77–84, 1957.

While the paper is intended more as an illustration than an investigation, some definite conclusions are apparent:

(1) As Dischinger; Bay; and Chow, Conway, Winter, and Morgan have previously illustrated, stresses in deep beams are highly nonlinear, often with considerable tension above and compression below the neutral axis.

(2) As these authors have also illustrated, the neutral axis is not always at the beam center, but shifts in position with beam dimension change and loading conditions.

(3) The stresses in deep beams are so affected by localized stresses caused by the loading and support forces that the relative positions of loads and supports are of great importance.

(4) The stresses in centrally loaded simply supported deep beams computed by the ordinary flexure formulas (Euler-Bernoulli theory) are seriously in error for height-span ratios above 0.67, although the maximum centerline tension computed by the ordinary methods agreed well with those measured for height-span ratios to about 1.0.

(5) For a given beam loading, the effect of increases of beam height on the stress pattern and stress magnitude above a height-span ratio of 2.00 is negligible. From author's summary

2045. Oshima, N., Equations of equilibrium of beams and plates by means of successive approximation, Proc. Sixth Japan nat. Congr. appl. Mech., University of Kyoto, Japan, Oct. 1956, 1–6.

2046. Minassyan, R. S., The theory of oblique bending of a compound prismatic beam (in Russian), *Trudi Gruz. politekhn. in-ta* no. 2, 143–152, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6983.

The interaction between the bending deflections caused by pairs of forces in the two principal inertia planes of a prismatic beam composed of materials of different elasticity is investigated. The problem leads to two boundary problems concerning a two-dimensional compound region (beam cross section). An example is given of a circular cylinder reinforced by a longitudinal bar of circular cross section.

The relationships between stresses, strains and displacements follow the "square-law" theory of elasticity.

A. K. Rukhadze

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2047. Shimanskii, Yu. A., Computation of the effects of a compression load on roofed beams (in Russian), Sb. statei po sudostroeniyu, Leningrad, Sudpromgiz, 1954, 18–28; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8477.

Reprint of an article by the author, published in 1930. The rule is established for the diminution of the compression on the beams in consequence of the transfer of part of the plate load in relation to the distance from the point of application of the load. With the help of the energetic method, the critical loading of the beam is ascertained, the rule of distribution of the shearing force transferred from beam to plate is clarified. As criteria of the stability of the surface covering supported by the beam, two conditions are put forward: the stability of the beam when unevenly compressed, and the stability of the surface covering under shearing forces transmitted from the beams. Diagrams and tables are presented which illustrate the practical application of the results obtained.

I. V. Svirskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2048. Pinadjan, V. V., An experimental investigation of the displanar distortion of bar cross sections under torsional bending deformation beyond the elastic limit (in Russian), *Dokladi Akad. Nauk Arm. SSR* **21**, 4, 163–166, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7757.

Results are presented of an experimental investigation into the elastic plastic deformations of the cross section of a thin-walled, steel bar of double-tee section under the action of a purely bidirectional moment. Two samples have been tested, of 626-mm length, with ratios of depth of section to wall thickness h/δ, of 19.2 and 16, respectively.

The tests were made on a 10-ton Zshopper press, the lower end of the test sample being rigidly fixed, while the bidirectional stress at the upper end was produced by a special device. The sample was loaded in three stages. The elongations were measured by extensometer gages.

The results obtained show that the hypothesis of displanar distortion of thin-walled bar, following a particular law, is also applicable beyond the elastic limit.

A. I. Strel'bitskaya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2049. Bychkov, P. G., The load carrying capacity of prismatic bars in combined bending and torsion (in Russian), *Trudi Mosk. torf. in-ta* no. 3, 181–207, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7758

A theoretical and experimental analysis of the load-carrying capacity of steel sample bars of circular cross section under simultaneous, and separate, bending and torsion.

A simplified diagram of the deformation stress and theory of place sections in deformation are adopted. The ratio between the torsional and bending moments is given.

The equation of the load-carrying capacity is presented by the author in the following form:

$$\sqrt{\left(\frac{M_b}{\overline{W}_b}\right)^2 + \left(\frac{M_t}{\overline{W}_t}\right)^2} = \sigma_{cr}$$

where M_b and M_t = bending and torsional moments at the limiting load-carrying capacity; $\overline{W}_b$ and $\overline{W}_t$ plastic moment of resistance of the cross section in bending and torsion respectively; σ_{cr} creep limit in tension.

The samples were tested in the form of a cantilever bar the free end of which is loaded in bending and torsion. The load was applied stepwise, directly on the scale pan.

The deflections of the bar ends were measured by an indicator and the torsional angles (in two sections) by a mirror arrangement.

The load-carrying capacity was considered to have been exhausted when the deformation exceeded the limit of proportionality for the particular loading stage, when the analytical stress condition of the sample practically breaks down,

The influence is investigated of a constant and a variable ratio of the torsional to the bending moments during the course of the test, the behavior of the sample on removal of the load, as well as under repeated loading of opposite sign.

A. I. Strel'bitskaya

Courtesy Referativnyi Znurnal, USSR
Translation, courtesy Ministry of Supply, England

2050. Fanelli, E., Finite length beam on elastic foundation (in Italian), *G. Gen. Civ.* **95,** 4/5, 276–282, Apr.-May 1957.

2051. Rvachev, V. L., Calculation pertaining to an infinite bar resting on an elastic semispace (in Russian), *Prikl. Mat. Mekh.* **20,** 5, 667–669, Sept.-Oct. 1956.

This is a general solution for the beam of infinite length and width—$2a$. The deflections of the beam are evaluated from the general properties of the elastic medium without any simplifying restrictions pertaining to the properties of the reaction forces of the elastic medium.

The basic differential equation of the non-restricted problem is $EIw^4(y) = g(y) - r(y)$; where $g(y)$ is vertical load per unit length and $r(y)$ the reaction of the elastic medium per unit length. Author assumes a solution in the form of:

$$W(y) = a(\lambda) \cos \lambda y$$
$$g(y) = b(\lambda) \cos \lambda y$$
$$r(y) = c(\lambda) \cos \lambda y$$

where λ is a random number.

In previous works he has proved that, in such a case, the deflection $w(x,y,o) = b(\lambda) \cos \lambda y$ and the pressure for this deflection on contact area is $p(x,y) = \varphi(\lambda,x) \cos \lambda y$, $-a > x > a$; here $\varphi(\lambda,x)$ is a function of E and μ of the elastic medium, x, and a complex expression of coefficient λ involving a and Mathew function, of a and λ.

From this, the values of coefficients a_i (λ) can be found, and the deflection is expressed as a load function in a solvable form. If the load function is expressed in Fourier integral form, the solution can be found for any load function and for even and non-even distribution of the reaction of the elastic medium across the width of the beam.

A. L. Nasvytis, USA

2052. Solianik-Krassa, K. V., The torsion of annularly grooved shafts (in Russian), *Trudi Leningr. politekhn. in-ta* no. 178, 238–252, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6842.

The problem is discussed of determining the stresses in a shaft of radius R with a circumferential groove of depth d, the boundary profile of which is an arc of a circle of radius a. An approximate equation is derived for the stress function Φ in the form of a series of partial solutions of the equation of Φ in bipolar coordinates ξ, η. This expression differs from that suggested earlier by the author ["The torsion of shafts of variable cross section", 1949, p. 136] in that it additionally incorporates, with a particular parameter κ, a partial solution containing an associated Legendre function

$$P_{-1/2,2}\,(\mathrm{ch}\ \xi)$$

The boundary conditions at the axis and on the boundary of the groove are

$$\Phi = C = \frac{M_k}{2\pi}, \text{ for } r = 0 \quad (M_k = \text{torsional moment})$$

$$\Phi = 0, \text{ for } \xi = \xi_0$$

and are rigorously satisfied, the last condition determining the coefficients of the series; in addition, for large values of z,

$$\Phi \approx \frac{C}{R^4}(R^4 - r^4), \ \Phi \mid_{z=R} = 0$$

The parameter κ is so selected that for shallow grooves the formula of the maximum tangential stress coincides with the usual formula

$$\tau_{max} = \frac{2M_k}{\pi R^3}\left(1 + \sqrt{\frac{d}{a}}\right)$$

P. P. Kufarev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2053. Epshtein, M. O., Limits of applicability of an approximate differential equation for a bent axis for use in calculating forces in bent bars (in Russian), *Trudi Leningr. in-ta aviats. priborostroenya,* no. 4, 87–90, 1955; *Ref. Zh. Mekh.* 1956 Rev. 6251.

For the eccentrically compressed bar a comparison is made of the results obtained for the displacement by an accurate and an approximate differential equation for the bent axis. The comparison showed that the determination of displacement (angles of deflection and bending) with the help of the approximate differential equation always gives somewhat exaggerated results, though the error increases rapidly when the axial force and its critical value approach each other.

The limits of applicability of the approximate differential equation also depend on the flexibility of the bar; for each flexibility there is its value relative to the eccentricity acting in such a way that the maximum stress is equal to the proportionality limit.

The separate questions of the influence of bending and the amplitude of eccentricity are not gone into. In the accurate equation for a bent axis a term is interpolated evaluating the effect of transverse force on the curvature. In the approximate solution (formulas 29–32), the influence of the transverse force is not computed. This makes it impossible to estimate the influence of disregarding the square of the first derivative in the expression for curvature separately from the influence of the transverse force on the curvature.

A. V. Dyatlov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2054. Azimov, B. A., Amenzade, Yu. A., Borissov, E. M., Belkina, G. L., and Katuzor, A. I., The solution of prismatic-bar bending problems on an electrical model (in Azerbeidjani), *Dokladi Akad. Nauk,* AzSSR **11,** 10, 665–673, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7678.

The solution is briefly described of the bending problem of a prismatic bar under a concentrated load, obtained on the EM-7 electric simulator. Cross sections are examined of an equal-armed cross, an unequal-armed cross, a rectangle, and a circle weakened by a central square cutout.

The obtained values of the shearing stresses, acting on points of the neutral axis, are compared with the corresponding stress values obtained by the Zhuravsky equation.

M. M. Manukyan

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2055. Ernst, G. C., Ultimate torsional properties of rectangular reinforced concrete beams, *J. Amer. Concr. Inst.* **29,** 4, 341–356, Oct. 1957.

Principal object of this investigation was to determine the quantity of transverse steel required to develop the yield point in longitudinal bars placed in the corners of rectangular beams subjected to pure torsion. Eighteen tests are reported: six each with

#3, #4, or #5 longitudinal bars, one in each corner. Transverse ties were spaced at 28, 14, 7, and 4 in., and also in pairs at 4 in. for each group, all of #2 size. One beam in each group contained no transverse reinforcement, and the nominal concrete strength of all groups was 4000 psi.

Results indicate that yield strains can be developed in longitudinal corner bars as well as in transverse ties, resulting in either a diagonal tension type of fracture or a hybrid failure in transverse shear and diagonal tension. Initial cracking corresponded to the failure of unreinforced concrete in torsion for all beams, at an average unit shearing stress of 312 psi. Evidence is also developed supporting the concept of a transition from elastic to plastic states of stress as the ratio of transverse to longitudinal steel approaches unity.

From author's summary

2056. Carter, W. J., Torsion and flexure of slender solid sections, *J. appl. Mech.* **25**, 1, 115–121, Mar. 1958.

Approximate elastic and elastic-plastic solutions of Saint-Venant torsion and flexural shear problems are obtained for slender sections with a variety of shapes, most of which are doubly symmetric. For slenderness ratios greater than 3, engineering approximations for maximum elastic shearing stress and torsional stiffness can be obtained by choosing a parabolic Prandtl-membrane whose form is appropriate to the width of the section. For elastic-plastic torsion, combination of Prandtl and Nadai analogies provides a simplified solution showing that the elastic zone has constant width. Examples of similar membrane approximations for elastic flexural shear indicate utility of method for various sections with slenderness ratios greater than 4. Author notes that very high boundary shearing stresses may occur in flexure of thin sections. Extension to elastic-plastic flexural shear of bars of symmetric section is indicated.

K. S. Pister, USA

2057. Yanpolsky, A. R., Calculation of the torsional rigidity of an anisotropic bar (in Russian), *Trudi Mosk. vech. mashinoste. in-ta* no. 2, 1955; *Ref. Zh. mekh.* no. 10, 1956, Rev. 6838.

The problem is investigated of the torsion of an anisotropic prismatic bar for the case when the cross section is bounded by two areas of curves intersecting on the x-axis

$$y = \lambda\Psi_1(x), \quad y = \lambda\Psi_2(x)$$

where λ is the minor parameter. To find the stress functions θ, φ, satisfying a known system of two differential equations, and the boundary conditions

$$X\frac{\partial\Phi}{\partial x} = C_1,\ Y\frac{\partial\Phi}{\partial y} = C_2,\ \varphi = C_3$$

(cf. S. G. Lekhnitoky: "The elastic theory of anisotropic bodies", 1950, pp. 93, 97, 149), the functions X, Y are sought in the form of series of the type

$$X = \sum_{i=0}^{\infty} \lambda^i X_i(x, t),\ t = \frac{y}{\lambda}$$

the terms of which are subjected to the following conditions on the contour:

$$X_0 = C_1,\ Y_0 = C_2,\ \varphi_0 = C_3$$

$$X_i = Y_i = \varphi_i = 0 \quad (i \geqslant 1).$$

Some first terms of the series for Φ and φ are indicated. For the construction of the elliptical cross section the series are summated, which leads to the known solution. The same method is applied to the determination of the stress function φ for the torsion of a bar, the cross section of which is an elastically symmetrical plane. For the symmetrical cross section $\Psi_2(x) = -\Psi_1(x)$ an estimate is given for the residual term of the series for φ. As an example, a detailed analysis is given of the case where the equation of the contour is $y^2 = \lambda^2 x(1 - x^2)$.

P. P. Kufarev
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2058. Trostel, R., Contribution to the calculation of spatially curved beams according to the theory of the first order (in German), *Ing.-Arch.* **25**, 414–423, 1957.

Author considers the theory of first order of approximation to the solution of spatially curved bars. After the section forces and section moments are established, he sets up the usual equations of equilibrium and assumes deformations to be very small in comparison with the dimensions of the structure. This leads to six third-order differential equations for the angle of twist and the statical deflection. The theory is illustrated with the solution of a cylindrical helical spring of circular cross section.

M. Maletz, USA

2059. Minkin, G. S., Evaluation of valve springs (in Russian), Sb. tr. Leningr. Otd. Vses. nauch. inzh.-tekhn. ob-va vod. transp. no. 2, 89–95, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8681.

Elementary calculations are used to determine the endurance of springs, statically and on account of fatigue. An investigation is made of the relation between the frequency of natural oscillation of the springs and the safety factor for fatigue, and a formula is obtained linking the calculated rpm of the cam shaft of a four-stroke engine and the safety factor of the valve spring.

A. F. Rozhnyatovskii
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2060. Dmitriev, B. S., The deformation of a tube wall in cold bending (in Russian), *Trudi Leningr. Korablestroit. in-ta* **17**, 32–45, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7750.

Bending was applied to tubes of 89–168-mm diameter. The amount of reduction in cross-sectional area of the tube walls was determined experimentally. From the experimental data it is found that the true wall thickness of the tube on the convex side is greater than the calculated value, as determined by the generally accepted formula: the amount of reduction in thickness of the wall of a tube bent to a radius R, equalling $2.8 - 3.0\,d$ diameters of the tube, does not exceed 13% of the (original) tube thickness; the wall thickness S, of the tube on the convex side, is suggested to be determined by the equation $S_1 = S/1 + 0.84(d/2R)$, S being the wall thickness of the straight tube.

V. G. Osipov
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2061, Wahl, A. M., Further studies of stress distribution in rotating disks and cylinders under elevated-temperature creep conditions, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-91, 8 pp.

A theoretical analysis of the stress distribution in solid disks and disks having central holes under steady-state creep conditions as imposed during spin tests. The relations derived are based on the assumption that creep rate can be expressed as a power function of stress multiplied by a function of time. The analysis indicated considerable nonuniformity of stress distribution, particularly for lower n-values and high ratios between outside and inside diameters. If a material had low ductility, the rupture life may be lower than if calculated on an average stress basis. Charts are presented for determining stress ratios for various diameter ratios, disk contours and n-values. Experimental data are needed to check the analytical work.

A. D. Schwope, USA

2062. Bolie, V. W., A new method for producing continuously adjustable gear ratios, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-146, 4 pp.

This paper describes a new method for providing continuously adjustable gear ratios. The method makes use of differential gears and speed reducers in a regular and systematic manner to provide gear ratios which can be adjusted easily with levers or electrically switched clutches. The system is readily adjusted by simple means to produce a specified gear ratio to any degree of accuracy. Once the desired gear ratio is selected, the input shaft is geared directly to the output shaft so that no slippage or steady-state error can occur, even for heavy loads. The system is easily adaptable to any range of desired gear ratios.

From author's summary

Plates, Disks, Shells, Membranes

(See also Revs. 1859, 1987, 1988, 1989, 2005, 2006, 2007, 2008, 2045, 2060, 2100, 2132)

Book—2063. Pfluger, A., Elementary theory of shells [Elementare Schalenstatik], Berlin, Springer-Verlag, 1957, vii + 112 pp.

This is a well-prepared expanded edition of an earlier book by the same author, "Einfuhrung in die Schalenstatik," Hermann Schroedel Verlag, 1948. This small book is divided into seven parts. In the first part, pages 1 to 5, a few remarks regarding the technical theory of shells are made. In the second part, pages 5 to 10, the membrane theory of shells having the form of a surface of revolution is treated. The usual cases of spherical domes, tank bottoms, cones, and shells of constant strength are discussed. Some information on stresses due to wind loads on cones is also given. Third part, pages 40 to 68, is devoted to bending theory of shells having the form of a surface of revolution. The theory is clearly developed and illustrated by examples of vertical cylindrical tanks subjected to hydrostatic pressure. An approximate solution for any rotational shell is also given.

In part four, pages 69 to 81, membrane theory of cylindrical shells is discussed, whereas in part five, pages 81 to 85, elements of the general membrane theory following Pucher are developed. This theory is applied to a hyperbolic paraboloid shell subjected to a uniform load. Part six, pages 85 to 90, is devoted to miscellaneous items of stress analyses. In the last part of this book, pages 91 to 110, besides a brief selected list of references, excellent tables of solutions for membrane stress resultants for variously loaded spherical, conoidal, conical shells, circular cylinders, cylindrical vaults, and for hyperbolic paraboloid shells are assembled.

This book can be warmly recommended to engineers studying theory of shells for the first time as well as to practicing engineers concerned with the design of the simpler types of shells.

E. P. Popov, USA

2064. Soehrens, J. E., The design of floating heads for heat-exchangers, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-247, 22 pp.

Paper contains the method for computing stresses of floating heads, loaded either by internal or external pressure, with respect to the continuity at the junction of the spherical head and the ring-shaped flange. As to the reactions of the gasket ring, two cases are considered: with loose radial displacement of the flange at the seat of the gasket and with the full gasket restraint. Usefulness of the derived formulas is shown on computing stresses of a typical floating head designed to withstand an internal pressure of 300 psi.

V. Kopriva, Czechoslovakia

2065. Svensson, N. L., The bursting pressure of cylindrical and spherical vessels, *J. appl. Mech.* **25**, 1, 89-96, Mar. 1958.

Assuming the stress-strain relation of the material of the vessel in the form of Ludwik's law, author derives expressions, including common strength material constants, which enable the determination of the pressure when bursting of the pressurized vessel can occur. For practical use simplified formulas are introduced. In the conclusion it is shown, provided the material characteristics can be adequately represented by the assumed law, that theoretical predictions are in an excellent agreement with experimental results.

V. Kopriva, Czechoslovakia

2066. Hodge, P. G., Jr., and Nardo, S. V., Carrying capacity of an elastic-plastic cylindrical shell with linear strain-hardening, *J. appl. Mech.* **25**, 1, Mar. 1958.

Authors present an application of the principle of minimum potential energy for piecewise linear isotropic plasticity [AMR **10** (1957), Revs. 750, 1758] to the problem of a simply supported circular cylindrical shell subjected to hydrostatic pressure. Elastic and plastic strains are considered, and the latter are assumed to follow a linear law of isotropic hardening. An approximate solution for the stress resultants, displacements, and maximum load is obtained by assuming a single half-sine deflection mode. It appears that, for the particular shell investigated, plastic behavior and elastic strains are both vital in determining the carrying capacity of the shell so that neither the rigid-plastic collapse load nor the classical elastic buckling load is a reasonable approximation to the true maximum load.

T. H. H. Pian, USA

2067. Layrangues, P., Calculation of membrane stresses in thin shell of revolution (in French), *Ann. Ponts. Chauss.* **127**, 5, 517-547, Sept.-Oct. 1957.

From the equations of motion for a thin shell in the form of a surface of revolution under given continuous normal load, the basic equations have been deduced for the particular case of a single sheet hyperboloid of revolution. The stresses produced by wind on a hyperbolic tower and an elliptical dome are then studied when the normal pressure at each point is $p_n \sin \varphi \cos n\,\theta$, where p_n is a function of integer n, φ the inclination of the normal at the point with the axis of revolution, and θ the angle between the meridian plane through the point and that containing the wind direction.

The linear differential equations with constant coefficients have been obtained and their capability for numerical solutions has been demonstrated.

From author's summary by S. C. Das, India

2068. Cooper, R. M., Cylindrical shells under line load, *J. appl. Mech.* **24**, 4, 553-558, Dec. 1957.

Problem of line load along segment of generator of simply supported circular cylindrical shell is treated using Naghdi's "shallow cylindrical shell equations" which include effect of transverse-shear deformation [AMR **10** (1950), Rev. 1378]. These equations reduce to Donnell's equations [*NACA Tecb. Rep.* 479, 1933] if transverse-shear deformation is neglected. Numerical example is investigated for shell with a length-to-radius ratio equal to 4, and for a radial line load acting along 1/20 of a generator, symmetrical with respect to the center of this generator. Results for stresses predicted by Donnell's equations are in excellent agreement with author's results. Radial displacements are underestimated by Donnell's equations if shell is comparatively thick, the discrepancies rising from 2 to 20% for a shell radius-to-thickness ratio decreasing from 25 to 5.

W. T. Koiter, Holland

2069. Windels, R., Bending theory of rotational shells with flat circular generatrix (in German), *Ing.-Arch.* **25**, 3, 164-173, 1957.

Approximate solutions for rotational shells with a shallow circular generatrix are established.

The usual simplifications commonly adopted in the theory of shells reduce the problem to the analysis of membrane stresses

with a perturbation in the form of a flexural stress wave near the edges. After the introduction of several approximations, the governing equations of the problems are represented by two homogeneous, partial differential equations of fourth order.

Special cases of aeolotropic and isotropic shells and of a shell with fin reinforcement are discussed and solutions indicated.

W. Ornstein, USA

2070. Behlendorf, E., Boundary-value problems in membranes and thin shells under membrane stresses (in German), *ZAMM* **36,** 11/12, 399–413, Nov./Dec. 1956.

Author develops a very interesting criterion in the form of three compatibility equations for the surface loading function and the boundary shear stresses so that one can tell whether a momentless state of stress exists in a thin shell. The curvature of the shell is assumed to be positive at all points.

The illustrative problem, unfortunately, is limited to the rather simple case of wind loading on a half sphere.

W. H. Hoppman, II, USA

2071. Simons, R. M., A power series solution of the nonlinear equations for axi-symmetrical bending of shallow spherical shells, *J. Math. Phys.* **35,** 2, 164–176, July 1956.

Author studies stresses and deformations of thin shallow segments of spherical shells subjected to uniform normal pressure and with simply supported edge (or with a clamped edge) without central hole.

As is known, the solution of the problem for small finite deflections depends upon two nonlinear equations of second order, in which unknown functions are β (negative of the angle of rotation of the tangent to a meridian) and $\psi = rH$ (H is the horizontal component of stress resultants).

Author gives a power series solution in which the two first coefficients F_1 and G_1 are determined with the boundary conditions, and in this paper are calculated with successive approximations.

Paper closes with a short paragraph on the stability of shells. Paper is a portion of a Ph.D. thesis accepted by Massachusetts Institute of Technology so that it is not always easy to understand analytical transformations and approximations.

G. Supino and P. Pozzati, Italy

2072. Fuchssteiner, W., and Schader, A., Generalized equations for shells (in German), *Beton u. Stahlbeton.* **51,** 7, 145–153, July 1956.

General shell surfaces are investigated under the following simplifying assumptions: (1) stress distribution across the shell thickness is linear; (2) shift in neutral axis caused by curvature of shell is disregarded; (3) deformations caused by stress-resultants normal to shell are negligible. Equilibrium equations are established for the general case of loading; first in terms of external load components, stress resultants and their derivatives, all referred to a fixed (arbitrary) reference system, and later in terms of the stress resultants acting in the plane tangential to the shell at the point considered. The stress resultants (in the tangential plane) are also expressed as functions of derivatives of displacements and rotations referred to the fixed coordinate system. Two particular cases are examined and compared with known solutions: the flat plate and the circular cylindrical shell. For plates, the agreement is complete; for the cylindrical shell there are small differences between Fluegge's solution and the present one. The differences are caused by variations in the initial simplifying assumptions.

No attempt is made to relate displacements directly to external loads (to derive higher-order differential equations by eliminating the stress-resultants) or to obtain solutions for the equations presented; the contribution of the paper lies in deriving basic equations that apply in all cases. G. Sved, South Australia

2073. Tsurkov, I. S., On elasto-plastic equilibrium of shells of revolution for small axisymmetric deformations, *Izv. Akad. Nauk SSSR Otd. tekh. Nauk,* no. 11, 106–110, 1956 (Translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., T-126, 7 pp.).

This note contains an application of a method given in "Plasticity" by Ilyushin. A sequence of functions is constructed from which forces and displacements can be determined to any approximation. M. Botman, Canada

2074. Vekua, I. N., A method for calculating prismatic shells (in Russian), *Trudi. Tbilissk. matem. in-ta* no. 21, 191–250, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6857.

Author defines a prismatic shell as an elastic body delimited above and below by surfaces

$$x_3 = h^+ (x_1, x_2),\ x_3 = h^- (x_1, x_2)$$

and laterally by cylindrical surfaces with vertical generating lines. The existence is assumed of a surface located between the aforesaid upper and lower surfaces and nowhere intersecting them within the limits of the particular shell. Thus the problem essentially concerns a plate of varying thickness, or slightly curved envelopes. The projection of this shell on the plane $x_3 = 0$ has the form of a multiply-linked region; i.e., the case of a perforated shell.

No physical considerations such as the Kirchhoff-Leew hypothesis are introduced. The reduction of the three-dimensional problem to the two-dimensional case is performed by resolving the stresses, strains, and displacements according to the variable x_3 into series by Legendre polynomials. Author calls the coefficients of these expressions the moments of stress, strain, and displacement relative to the polynomial of one or another degree.

For these moments, differential equations are derived. It is demonstrated that, if the series are interrupted at the N-th term (counting the first item as the zero item) then, for $3N + 3$ moments of displacement (with reference to polynomials of the order $0.1, \ldots N$) $3N + 3$ simultaneous equations are obtained. The theorem is proved of the existence of a solution for this system only on the assumption that, on the lateral boundaries of the shell, conditions of the same kind must be satisfied as for the three fundamental problems of the theory of elasticity.

Special consideration is given to the cases of $N = 0$ and $N = 1$. In the case of $N = 0$, equations are obtained for determining the moments of tangential displacement, which generalize the equations of the two-dimensional problem. Determination of the moment of normal bending is at the same time reserved as a special problem.

The case of $N = 1$ leads to a complex system of equations in the four stress functions. These are, however, considerably simplified for symmetrical (with reference to the plane $X_3 = 0$) prismatic shells; in such case, the system of simultaneous equations becomes resolved into two subsidiary systems (each relating to two stress fractions). In the physical sense, this corresponds to a resolution into inertialess and inertia conditions of stress.

As a particular case, symmetrical plates of constant thickness are examined, and it is shown that integration of the corresponding equations can be performed by the method developed by N. I. Muskhelishvili for the two-dimensional problem of the theory of elasticity. A. L. Gol'denveizer

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2075. Karlsson, K. I., On the stability of the steel lining in a vertical penstock shaft, *Acta Polyt.* no. 211, *Mech. Eng. Ser.* **3,** 10, 22 pp., 1957.

Variational principle has been employed to discuss stability of deformation of the (title) shell inside a hollow under pressure of

water entering into minute gap between the shell and hollow, "m" sections of its circular contour being supposed to yield inward and remaining "m" interspaces outward by deformation. A second-order differential equation in the radius of curvature is obtained to express elastic equilibrium under pressure. Author shows that equilibrium of a free undistorted shell, for pressure $< 3\,EI/a^3$ is stable, a being the radius of the shell. Equilibrium of a slightly distorted shell is also stable. For integer $m > 2$ the equilibrium is unstable. The case when the shell gets in contact with the hollow over an arc is also discussed. Such contact is possible till pressure does not exceed a certain value depending on $a' - a$ and m when a' is the radius of the hollow. D. N. Mitra, India

2076. Nakamura, K., Calculation of stresses in pressure vessel heads. Report 2, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 149–152.

The proposed calculation procedure for the stresses in the ends of a cylindrical pressure vessel having a comparatively large crown radius and small heel radius is based on the Love-Meissner shell theory. For the flat spherical part, basic equations of the Bessel type were used (after replacing cot φ by $1/\varphi$). In the toroidal small heel radius part, Clark-Reissner equations were used and necessary functional relations tabulated by the author [*Trans. Japan Soc. mech. Engrs.* **19,** 83, 54–58, 1953]. Results are compared to previously published numerical solutions of complete Love-Meissner equations and are generally in good agreement. The maximum moment and shear are only nonconservative by five per cent. Specific comparison is made for case where, in terms of cylinder radius b, $r_0/b = 2$, $r_1/b = 0.182$, $b/b = 0.03$.

M. L. Williams, USA

2077. Williams, M. L., Further large deflection analysis for a plate strip subjected to normal pressure and heating, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-14, 8 pp.

In an earlier paper [AMR **9,**(1956), Rev. 2471] author determined stresses and deflection in an infinite strip plate undergoing large deflections (nonlinear regime) when the plate is subjected to a combined normal loading and uniform temperature rise through the thickness, both variable across the plate width. The present paper extends the analysis and design charts to the case where the temperature may have any desired distribution through the thickness of the plate. With the usual plate assumptions (plane sections remaining plane), the arbitrary temperature distribution can be represented completely by the average temperature and the "first temperature moment" about the middle surface, as far as the engineering stresses and deflections are concerned. The convenient nondimensional design charts cover equilibrium positions in the buckling and nonbuckling range and show maximum stress and central deflection as a function of pressure, average temperature, and temperature moment for cases of both clamped and simply supported edges.

The formulation has been based upon an energy approach. Author remarks that the calculated range of variation of parameters falling in the region between thick plate and membrane solutions ($1 \leqslant w(0)/h \leqslant 4$; $w(0)$ central normal deflection, h thickness) may be completely sufficient. M. Schafer, Germany

2078. Gladwell, G. M. L., Uniqueness theorem for thin clamped anisotropic plates, *Mathematika* **4,** 1, no. 7, 70–75, June 1957.

Paper deals with problems of transverse displacements of thin anisotropic plates with the most general type of diagonal symmetry. Proofs of uniqueness of solutions under certain conditions are given for problems of plates occupying both finite or infinite regions. This is a generalization to anisotropy of the uniqueness theorems given by Tiffen [*Quart. J. Mech. appl. Math.* **8,** p. 237, 1955] for isotropic plates.

From author's summary by H. G. Lew, USA

2079. Mansfield, E. H., The inextensional theory for thin flat plates, *Quart. J. Mech. appl. Math.* **8,** 3, 338–352, 1955.

Paper presents an elegant *inextensional* theory for thin flat plates. The theory is applicable to cantilever and other plates subjected to a normal loading which is resisted primarily by the flexural rigidity rather than by the extensional rigidity. For such plates, the deflection surface approaches a developable surface. Paper gives a general method and several examples, with some evidence of experimental verification. (The reconciliation of the inextensional theory with the full von Karman plate equation has been discussed previously by Fung and Wittrick, see AMR **9,** Rev. 97). Y. C. Fung, USA

2080. Grinberg, G. A., and Poplavskii, R. P., Bending of semicircular thin plates with restrained circular edge and free edge (in Russian), *Inzhener. Sbornik, Akad. Nauk SSSR* **18,** 83–88, 1954.

Thorough analysis of a thin semicircular plate for any type of loading on the basis of elastic deflections expressed in polar coordinates. Method is demonstrated by numerical example, assuming uniformly distributed load. It is also explained how this method can be applied to this structural type under other conditions; e.g., similar plate freely supported around the circular boundary. Author refers also to paper discussing the method analyzing rectangular thin plates originated by P. F. Papkovich [*Prikl. Mat. Mekh.* **12,** 1953]. J. J. Polivka, USA

2081. Vodicka, V., Bending of a circular plate with a concentric hole (in Polish), *Rozprawy Inz.* **5,** 1, 3–12, 1957.

A case of bending of a plate in the form of a ring of constant thickness is considered, the plate being subjected to uniform concentric load. Two kinds of plate support are considered: (1) at the outer edge, (2) at the inner edge. T. Rajfert, Poland

2082. Sekiya, T., and Wada, Y., Bending of circular plates loaded over the arbitrary eccentric circular domain, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 145–148.

Authors consider plates with concentric hole and with different conditions on inner and outer boundary. The lateral load on the eccentric circular domain is axisymmetrical with respect to the center of this circle. Results are expressed in Fourier series and are applied in two numerical examples. M. Kuipers, Holland

2083. Saito, A., and Hirai, N., Bending of circular plate loaded along radius or circular arc, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 141–144.

The distribution of the external load is expressed by means of δ-function, and the particular solution of the plate equation is expanded into Fourier series. Authors give theoretical results for different boundary conditions and types of loading in the form of infinite series. There are two numerical examples.

M. Kuipers, Holland

2084. Sherman, D. I., Bending of a circular plate partially supported and free along its circumference (in Russian), *Doklady Akad. Nauk SSSR (N.S.)* **105,** 6, 1180–1183, Dec. 1955.

2085. Bogdasarov, A. D., Distribution of stresses in a round plate with free edges, performing axial-symmetrical oscillations (in Russian), *Trudi. Sredneaz. un-ta* no. 37, 173–181; 1954; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8541.

A search is made for the stresses in the central area of the plate, when under the influence of natural bending of an axially symmetrical round plate with free edges. The forces of inertia in the area of the plate are considered to be insignificantly small.

V. V. Bolotin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2086. Goldberg, A. M., The stress distribution in plates with reinforced round holes (in Russian), *Trudi. Leningr. politekhn. in-ta* no. 178, 200–231, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6832.

The stresses in a plate at a reinforced round hole are analyzed.

The stress function for the continuous plate is applied in the form

$$F_0 = a_0 r^2 + a_1 r^3 \cos\theta + a_1' r^3 \sin\theta + \sum_2^\infty (a_n \cos n\theta +$$

$$+ a_n' \sin n\theta)\, r^{n+2} + \sum_2^\infty (b_n \cos n\theta + b_n' \sin n\theta)\, r^n$$

The stress function for the plate and reinforcing ring is applied in the form suggested by Mitchell.

The coefficients of these functions are determined from the boundary conditions on the contour of the joint between the plate and the ring and the conditions at infinity.

An example is analyzed and curves given for the stress distribution in a wedge (triangular plate) with a reinforced round hole when a hydrostatic pressure is applied to one edge of the wedge.

M. P. Sherenet'ev
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2087. Ku, C. L., On the large deflection of elastic circular membrane with initial tension under uniformly distributed load (in English), *Scientia Sinica* **5**, 3, 423–443, Sept. 1956.

The problem of large deflections of elastic circular membranes under uniform side load but without initial tension has been discussed by Hencky, Wei-Zang and Alexeev. The present paper adds to these discussions by presenting solutions for the case of elastic circular membranes under uniform side load *including initial tension.* Solutions of the pertinent differential equation are given in series form. The solutions are summarized by a large group of figures which present numerical data that may be used in practical applications. Finally, questions of vibrations of membrane devices subjected to large deflections are discussed.

R. L. Bisplinghoff, USA

2088. Szelagowski, F., The influence of a bolt inserted in a hole on stress distribution in an infinite plate subjected to simple tension or compression (in Polish), *Arch. Mech. stos.* **9**, 1, 3–18, 1957.

The bolt in the hole has the same diameter as the hole and different elastic properties than those of the plate. Expressions for stresses in the plate, the length of the contact surface between the plate and the bolt, and the maximum values of pressure against the bolt are obtained, if the plate is subjected to simple compression or tension.

J. Mossakowski, Poland

2089. Choudhury, P., Stress distribution in a thin aeolotropic strip due to a nucleus of strain, *ZAMM* **36**, 11/12, 413–416, Nov./Dec. 1956.

Author presents a solution of the problem of a thin orthotropic (aeolotropic) plate loaded by two concentrated forces parallel to coordinate axes and applied at the origin, and then solves the problem with the nucleus of strain at the origin. These general results are applied to a thin orthotropic strip for which formulas for stresses are derived by using Fourier transform.

T. Leser, USA

2090. Matumoto, T., Some singularities in solution of the semi-infinite plate loaded on its straight boundary, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 31–34.

Analyses of a semi-infinite plate and an infinitely long plate with finite width under vertical and horizontal triangular and rectangular loadings on the straight boundaries are given. Analyses show that the displacements on the boundary do not tend to zero at distances, but are only present in the semi-infinite plate.

T. H. Lin, USA

2091. Hayashi, I., The orthotropic plate subjected to forces on its circular hole, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 47–50.

2092. Kubo, T., Stresses on the orthogonally aeolotropic plate with a row of holes, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 51–55.

2093. Kozhevnikova, V. N., The stress distribution at a rectangular cutout in an infinite plate bent in its own plane (in Russian), *Nauk. zap. Lvivsk. un-ta* **29**, 1, 6, 112–130, 1954; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7688.

The method of N. I. Muskhelishvili is applied to the stress analysis of an isotropic beam or plate in pure bending, weakened by a rectangular cutout with rounded corners and slightly bent sides; more particularly, at a cutout whose contour is represented by

$$z = \omega(\zeta) = A[1/\zeta + c_1\zeta + c_3\zeta^2 + \cdots + c_n\zeta^{n+\cdots}]$$

wherein $\zeta = \rho e^{i\vartheta}$, retaining three terms for square, and six for rectangular cutouts with aspect ratios of $a:b = 1,\ 1.4,\ 1.5,\ 2.0,\ 2.5,\ 2.9,\ 4.35$, and $a:b = 1:1.4,\ 1:1.5,\ 1:2.0,\ 1:2.5,\ 1:2.9,\ 1:4.35$.

The problem is solved for a plate of infinite extent. The influence of the rounding of the corners of the cutouts, on the stress concentrations thereat, is investigated. Diagrams are presented of the stress patterns in the cutouts at the more characteristic cross sections.

G. N. Savin
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2094. Kurdyumov, A. A., On the joint work of ribbing and deck (in Russian), *Trudi. Leningr. Korablestroit. in-ta* no. 15, 12–15, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8478.

An investigation is made of the joint work performed when the plating and supporting ribs are subjected to deflection. It is assumed that the plating is under a transverse loading and jointly with it the connected ribs are subjected to longitudinal compression forces. The plating is considered to be orthotropic, while the torsional stiffness of the ribs is disregarded. A solution of the problem is designated for the plate with two freely open edges and a large number of identical ribs, in the longitudinal and in the transverse or in both directions. The development of the solution of the problem of the stability of the plating with one or with two ribs is indicated. It is shown when it is more convenient to make use of the concept of the reduction coefficient.

G. G. Rostovtsev
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2095. Rothman, M., Stresses in a plate containing a crack; a theoretical investigation, *Engineer, Lond.* **184**, 4770, 174–175, Aug. 1957.

2096. Wigglesworth, L. A., Stress distribution in a notched plate, *Mathematika* **4**, 1, 7, 76–96, June 1957.

Problem considered is determination of stresses and displacements in a semi-infinite elastic plate containing a thin notch perpendicular to its edge. A general mathematical solution is presented which is carried through to numerical results for a plate which in the absence of the notch would have a uniform tension parallel to the edge. The solution is obtained by Muskhelishvili's method and makes use of Mellin transforms to reduce the mathematics. Several useful tables for the functions involved in prob-

lems of this type are given. The stresses near the root of the notch are given in an approximate formula. In addition, exact numerical values are given for distances from the root of the notch of one and two tenths of the notch depth. The maximum principal stress at a distance from the root of one tenth of the notch depth is less than 3.3 times the applied tension at points remote from the notch. When angles are considered measured from the notch, the maximum shear occurs at 90° and the maximum principal stress occurs at 120° in the immediate vicinity of the root of the notch.

S. Levy, USA

Buckling Problems

(See also Revs. 2042, 2105)

2097. Patel, S. A., and Kempner, J., Effect of higher-harmonic deflection components on the creep buckling of columns, *Aero. Quart.* **8,** 3, 215–225, Aug. 1957.

Paper investigates the effect of higher harmonic deflection components on the deflection-time characteristics of an H-column with nonlinearly viscoelastic creep properties. The creep law is of the form $\dot{e} = \dot{s}/E + s^m/E_1$, and is the same for tension and for compression. The differential equation of bending of the column with initial deviation from straightness is solved numerically for $m = 3$, taking into account the effects of the three first harmonics only. It is shown that second and third harmonic deflection components reduce the column lifetime significantly only when their initial amplitudes as well as the initial amplitude of the first harmonic component are very large. It is shown that the second harmonic components have a much smaller effect on the column behavior than do third harmonic components.

A. Phillips, USA

2098. Gossi, A., A cantilever column under axial and transverse loads (in Italian), *G. Gen. civ.* **94,** 7/8, 507–526, July/Aug. 1956.

A cantilever column with many sections (each of constant thickness) under arbitrary loads is dealt with by a step-by-step procedure: moments and angles are calculated from the well-known solution of the column equation together with the conditions of transition, and the unknown moment at the built-in end is found from the condition $M = 0$ at the free end. Application is made to the stability problem (also in the form of the so-called ω-method) and to various numerical examples; comparison is made with approximate solutions.

In reviewer's opinion the procedure would be much more perspicuous by the use of the matrix notation; see, e. g., reviewer's paper [AMR **9** (1956), Rev. 3179], where the generalization of author's basic idea to a column of arbitrary boundary conditions is described.

K. Marguerre, Germany

2099. Shaushiashvili, A. M., The calculation of centrally compressed steel columns for stability in torsion (in Russian), *Trudi Gruz. politekhn. in-ta* no. 33, 9–16, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6987.

The stability of a centrally compressed thin-walled cylinder reinforced by longitudinal strips is examined. On the basis of the equations of spatial stability, developed by V. Z. Vlassov for a profile with two axes of symmetry, author derives analogous equations for the present problem, special equations being developed by the author for the limiting cross sections. Curves are given for calculating the critical load.

R. A. Mezhlumyan

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2100. Yamaki, N., Buckling of a circular plate under locally distributed forces, *Rep. Inst. high Speed Mech., Tohoku Univ.* **8,** 13–24, 1957.

The title problem is solved by the Ritz method for the cases where the edges are either clamped or simply supported and have uniform compressive loads applied to diametrically opposite small widths of the circumference. The problem is solved for either case of edge fixity, and the buckling loads and deflection surfaces for various values of the load width are calculated and the results graphed and discussed.

From author's summary by A. L. Ross, USA

2101. Sundstrom, E., Creep buckling of cylindrical shells, *Trans. roy. Inst. Technol. Stockholm* no. 115, 27 pp. + 9 figs. + 7 tables, 1957.

An analysis is made using a modified form of the creep rate expression of Odqvist to determine the critical buckling time of a cylindrical shell subjected to external pressure. A double membrane analogy is made for the cylindrical wall, i.e., the wall construction is assumed to be similar to that used in aircraft sandwich construction in that the skins take membrane loads only, while the core can only support forces normal to the shell and shear stresses in planes parallel to the shell. Conditions at the center part of the shell are shown to determine the lifetime, whereas end conditions have little influence. A trigonometric series is assumed for the deflection.

Poor agreement with actual results should be expected when the axial compressive stress is higher than the circumferential stress, when the tube is very short, or when the bulkheads resist warping thus preventing an even distribution of axial stress. Best agreement is to be expected for tubes whose length is greater than their diameter.

The formula may be used for curved panels the edges of which are hinged to a stiff frame. Diagrams and tables of the stress distribution and lifetime are given.

From author's summary by A. L. Ross, USA

2102. Lobovikov, A. S., The stability of three-dimensional frameworks (in Russian), *Nauch. tr. Leningr. inzh.-stroit. in-ta* no. 17, 101–120, 1954; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6980.

Author repeats the conclusions and examples of calculations for the stability of frame structures published by N. V. Kornoukhov [*Vestn. inzh. i tekhnikov*, no. 2, 1939], in which an expanded form of the method of deformations in the theory of stability is used. The present paper expounds the canonical form of the method of deformations by using the problem of the stability of the simplest single-span, single-storey, orthogonal frame structure, the solution of which is given in the cited article. The classical form of the method has been developed in detail by A. F. Smirnov ["The static and dynamic stability of structures," Moscow, Transzheldorizdat, 1947].

N. K. Shitko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2103. Starshihov, K. K., Revision of the standard rules for the stability calculation of single-storey frameworks (in Russian), *Trudi Novosibir. in-ta inzh. zh.-d. transp.* no. 11, 316–322, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6981.

It is pointed out that in the Technical Conditions for the design of railway bridges (TUPM-47, MPS), the formula for the calculation length of the uprights

$$l_p = \mu l_0 \quad (\mu = 1 : 1.5),$$

where l_0 is the total length of the upright, may lead to grave error. From solutions cited in the literature, revised recommendations are made for frame stanchions under exclusively axial compression.

Frames with elements in combined bending and compression are not considered. B. M. Broude

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Joints and Joining Methods

(See Rev. 1949)

Structures

(See also Revs. 1877, 1891, 1923, 1994, 1995, 1996, 2000, 2013, 2094, 2102, 2103, 2243, 2370, 2371)

2104. Popov, I. G., The calculation of some statically indeterminate systems by means of an equation of one unknown (in Russian), *Nauch. tr. Leningr. inzh.-stroit. in-ta* no. 17, 77–100, 1954; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7860.

The problem is examined of transforming a system of linear equations, obtained for the analysis of statically indeterminate systems, into single equations, each with the unknown. Problems are investigated, the solution of which is reduced to a system of trinomial equations, on the condition that the first and last equations each contain two unknowns; more complicated problems are also studied.

The suggested method can be utilized for calculation both by the method of forces and by the method of displacements. With a small number of equations, all operations can be performed sufficiently accurately on a slide rule.

Numerical examples are given of the application of this method to a number of statically indeterminate systems.

A. I. Strel'bitskaya

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2105. Vorontsov, G. V., The problem of the stability analysis of complex frameworks by resolution into simply equistable systems (in Russian), *Nauch. tr. Novocherkassk. politekhn. in-ta* **26,** 112–119, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7848.

Some proportions are developed, set up by N. V. Kornoukhov, for the problem of the stability analysis of complex frameworks by simplifying the calculation scheme [N. V. Kornoukhov, "Strength and stability of bar frameworks," Gosstroyizdat, 1949, Chap. XI].

An alternative method is suggested for finding the critical load values of complex systems by means of curves; the required critical load being limited by its boundary values, and determined with suitable accuracy by a series of successive approximations.

The method is illustrated by examples of the calculation of single-panel (single bay), two- and three-storied trusses.

A. F. Anishchenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2106. Woolf, S., The effect of symmetry and repetition in simplifying the analysis of structures, *Struct. Engr.* **35,** 9, 357–363, Sept. 1957.

2107. Cohen, J. S., Tables for the design of rectangular beams and slabs according to the new code, *Concr. constr. Engng.* **52,** 8, 265–277, Aug. 1957.

2108. Nakamura, S., The new solution and calculation of arch loaded with a torsional moment, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 171–174.

General solution for arches fixed against torsion and loaded by twisting moments is derived, using certain simplifying assumptions. Several examples are discussed. Presentation and, in particular, sketches in postage-stamp size, are not easily understood. H. Craemer, Germany

2109. Slovinskii, V. A., Prestressed arches with tie beams (in Russian), Tbilisi, 1953, 35 pp. 70 kop.; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8696.

The question of construction and calculation of spanned bridges is gone into when the design incorporates an arch with prestressed condition of the suspensory and transverse beams. Examination was made of two variants of prestressing: (a) prestressing of tensioning is carried out by means of an even tension stress of the reinforced endings until the arch is completed without elimination of the supplementary deflection moments in the system; (b) the same, with a temporary joint, guaranteeing the working of the arch from a constant lead without supplementary moments. An example is given of the arch construction, with prestressed tensioning, with a span $L = 55$m and f, rise of arch of 13.75m under the load of train N8, used for calculation, with detailed descriptions for the tensioning devices and arrangements. A scheme is evolved for the calculations based on the general state of structural mechanics and "Instructions for designing prestressed ferro-concrete constructions" (Moscow, Goestroizdat, 1951).

Results are put forward for the experimental investigations of pre-stressed flexible structural compounds from the point of view of their stability. G. L. Pavlenko

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2110. Malkina, R. L., Calculations of girder and frame systems with thin-walled structural members by the method of successive approximations (in Russian), *Trudi Ural'skogo politekhn. in-ta* **54,** 82–102, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8593.

The theory for calculation of thin-walled bars as developed by V. Z. Vlasov ["Thin-walled elastic bars," Stroitizdat., 1940] and A. A. Umanski ["Torsion and deflection of thin-walled members in aircraft structures," Oborongiz., 1939] is expanded to meet the cases of girder and frame systems. The method recommended by successive approximations is based on the idea in the method of distribution of the moments of entrapping. Examples are given of calculations of multispan girders and frames made up from thin-walled sections. E. I. Silkin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2111. Walther, R. E., Investigation of multibeam bridges, *J. Amer. Concr. Inst.* **29,** 6, 505–526, Dec. 1957.

After an introductory reference to the load-carrying system of multibeam bridges (theory of orthotropic plates) the paper reports findings of tests on a large-scale model bridge of prestressed concrete. It is shown that such a bridge can accurately be analyzed as an orthotropic plate. The influence of factors which affect the behavior of the structure—slip between adjacent beams, interaction of shear keys, degree and location of lateral post tensioning, etc.—have been studied. Empirical formulas for the relationship of the stiffness properties are derived.

From author's summary

2112. Vassiliev, G. A., The calculation of perforated partitions erected on the admission side of horizontal water-supply settling basins (in Russian), *Tr. Kostovsk.-na-Donu inzh. stroit. in-ta* no. 4, 234–242, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8238.

It is proposed to specify the diameter of the perforations in such a partition as the smallest practicable under particular manufacturing conditions and to determine the entry length in the settling

basin in such manner that the conically-expanding jets, upon confluence, shall occupy the whole flow cross section.

P. G. Kiselev

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2113. Brandt, A., Kosmowski, J., and Wasiutynski, Z., On the design of lattices for minimum potential by displacing non-loaded nodes uniting three bars (in Polish), *Rozprawy Inz.* **5**, 2, 157–205, 1957.

Paper is devoted to the analysis of conditions determining the location of a non-loaded node, uniting three bars of lattice of uniform strength corresponding to the minimum value of the potential of the lattice.

The basis of the present investigations is equations, derived at the beginning of the paper for partial derivatives of the potential of the lattice with respect to the lengths of two outer bars, having their ends at the given node. Further considerations include an analysis of the conditions of appearance of zero values of these derivatives, the determination of the cases of existence of extremum values of the potential, and, finally, an analysis of the variability of the potential in function of the location of the non-loaded mode.

Finally, some examples of lattice design for minimum potential are given using the method of displacement of non-loaded nodes uniting three bars. J. Czulak, Poland

2114. Konishi, I., Komatsu, S., and Ohashi, M., Stress analysis and calculation for design of composite box girder bridge (in Japanese), *Trans. Japan Soc. civ. Engrs.* no. 25, 1–28, Mar. 1955.

According to classical bending torsion theory, an analysis is made of the stress distribution during the eccentric loading in composite box girder bridge, which can not be solved as easily as a girder having the I-type section is treated in design.

To illustrate the method of calculating, numerical example is shown for a simple-span bridge, which is situated at the town of North Bend, in King County, Washington, and has two all-welded steel box girders made up of thin plates.

In first part of this numerical example, the maximum normal stress σ_{max} and shearing stress τ_{max} are obtained under two kinds of live loads; namely

(1) H15-44 prescribed by AASHO;

(2) The second kind of load prescribed by Japan Highway Bridge Design Specification.

In second part, two influence lines of σ_{max} at the middle section in one side box girder of a pair are found for two typical cases of transversely moving load;

(1) Uniformly distributed line load in spanwise;

(2) Concentrated load.

The ratios of two ordinates at the center positions of both box sections are 0.61 : 0.39, and 0.69 : 0.31 in the first and second case, respectively. These ratios are nothing but the distribution rates of loads for maximum normal stress corresponding to both loading conditions. At the same time, the influence lines of the same kind concerning τ_{max} value at the end section are drawn under above two loading conditions. The first loading gives the distribution rate 1.16 : -0.16 and the second 0.91 : 0.09.

Comparison between the results obtained by this theory and ones by the conventional method shows explicitly how large the error is when the latter is applied to box girder.

Summarizing the noticeable facts described above, authors present the more rational method of calculating for such box girder as the North Bend one. S. Okamoto, Japan

2115. Richardson, J. T., and Olsen, O. J., Arch dams: Stress studies for Ross and Diablo dams, *Proc. Amer. Soc. civ. Engrs.* **83,** PO 3, (*J. Pow. Div.*) Pap. 1267, 27 pp., June 1957.

Paper presents representative results of a long-time study of stress from strain meters at Ross Dam. Included is an outline of the method followed in deriving stress from embedded strain meters. Also presented are the preliminary results obtained from a stress study of the Diablo Dam by strain relief measurements.

From authors' summary

2116. Koranyi, I., The effects of shear on the stress distribution of continuous steel girders (in Hungarian), *Az Épitõipari és Közlekedési Müszaki Egyetem Tudományos Ülésszakának Elõadásai* no. 11/12, 79–99, Nov. 1955.

In the analysis of continuous girders, effects of shear are usually neglected. As first pointed out by Timoshenko and subsequently by Stüssi, the deformation due to shear may in some instances become too great to be disregarded. Investigations of Stüssi on cantilevered beams showed considerable deformation due to shear. These have prompted the author to conduct similar investigations on simply supported and continuous girders. Results of these investigations are published in Vol. I. of his book, entitled "Statical analysis of structures," in which the significance of these effects is dealt with, particularly in case of welded steel I(—)beams (8—13%). As specifications of the recent Hungarian Building Code of bridges concerning accuracy are rather severe, the problem of shear effects in continuous girders becomes of importance. Solutions for special cases have already been given by Maier—Leibnitz. In the present paper, author describes a general method for the analysis of continuous girders. This method, while taking effects of shear into consideration, accepts the validity of Bernoulli's assumption (plane cross sections remain such after deformation). Following the general theory, numerical examples are given for different cases (varying spans, varying cross section) showing that the effect of shear on *maximum* stresses is negligible even in accordance with recent specifications. From author's summary

2117. Anderson, R. A., Weight-efficiency analysis of thin-wing construction, *Trans. ASME* **79,** 5, 974–979, July 1957.

Weight-efficiency information on solid and sandwich plates in compression is reviewed and used to present similar efficiency curves for multiweb thin-wing construction. Relative weights of channel and corrugated web construction, sandwich covers and full-depth honeycomb construction, in aluminum, titanium, and steel material are compared at room temperature and 600F as a function of loading intensity. Simple criteria are given for estimating the weight increments resulting from changing material properties. R. R. Heldenfels, USA

2118. Gerard, G., Thermostructural efficiencies of compression elements and materials, *Trans. ASME* **79,** 5, 967–973, July 1957.

Equations relating minimum weight of compression elements to structural loading intensity are derived and used to construct charts from which the most efficient structural configuration and material for carrying compression loads can be determined. Elements considered include solid and wide columns, plates and plate assemblies, optimum stringer panels, stringer panel-rib construction, and multiweb construction.

R. R. Heldenfels, USA

2119. Schnitt, A., Brull, M. A., and Wolko, H. S., Optimum stresses of structural elements at elevated temperatures, *Trans. ASME* **79,** 5, 959–966, July 1957.

A systematic procedure is described by which the optimum arrangement of protected or unprotected structure can be determined for a given loading and exposure to elevated temperature. A transformation method is used to derive optimum-stress curves for wide columns and multiweb beams for a given material at any temperature from experimentally proven optimum curves for a dif-

ferent material. The only data required are the stress-strain curves of the materials. Relationships are also developed for determining the size and geometry of the derived optimum structure, and an approximate means for determining creep lifetime is suggested. Then, additional equations are developed which permit comparison of relative weights of insulated and cooled structures with unprotected structures for elevated temperature service. It is concluded that use of a protected structure of aluminum or magnesium results in significant weight savings in many applications. R. R. Heldenfels, USA

2120. Goldman, G. M., Discussion on safety-factor requirements for supersonic aircraft structures, *Trans. ASME* **79,** 5, 986–989, July 1957.

A safety-factor procedure for supersonic aircraft is proposed which the author believes can be developed to provide adequate safety reserves in new designs. Present safety-factors of "cold" aircraft are discussed first and then the structural problems of the "hot" airplane are considered. The design problems including temperature effects are summarized and the type of safety allowance needed for each is indicated.

R. R. Heldenfels, USA

2121. Goldin, R., Design criteria for heated aircraft structures, *Trans. ASME* **79,** 5, 980–985, July 1957.

The objective is to assemble a practical structural design philosophy for airframes that must sustain aerodynamic heating. The present procedures used to establish structural criteria are first examined and the influence of thermal aspects on these criteria is considered. Proposals relative to safety factor, creation of limit load-and-temperature condition combinations, and how to introduce creep life are then presented with illustrative examples of criteria for two types of aircraft. Because of the vast number of limit conditions for heated structures, author concludes that it is impractical to define specific combinations as in current requirements, and future specifications should be concerned with a fundamental criteria framework.

R. R. Heldenfels, USA

2122. Rickett, G., and Iyengar, K. T. S. R., Stress concentration in post-tensioned prestressed concrete beams, *J. Technol.* **1,** 2, 105–112, Dec. 1956.

The use of the multiple Fourier method to analyze the stress distribution in the end regions of a posttensioned prestressed-concrete beam has been shown. The multiple Fourier method demonstrated here is a relatively new method for solving those problems for which the "Saint Venant principle" is not applicable.

The actual three-dimensional problem and a two-dimensional simplified representation of it are treated. The two-dimensional case is treated first and rather completely to gain further experience with multiple Fourier procedures. The appropriate Galerkin vector for the three-dimensional case is found and the required relations between the arbitrary functions are stated.

From authors' summary

2123. Savona, J. S., Design based on the stress in the reinforcement, *Concr. constr. Engng.* **52,** 10, 345–347, Oct. 1957.

2124. Drucker, D. C., Plastic design methods—advantages and limitations, Soc. nav. Arch. mar. Engrs. Prepr. no. 2, 19 pp., Nov. 1957.

2125. Drucker, D. C., and Shield, R. T., Bounds on minimum weight design, *Quart. appl. Math.* **15,** 3, 269–281, Oct. 1957.

Authors have used the static (or lower bound) theorem and the kinematic (or upper bound) theorem for collapse loads of elastic-perfectly plastic bodies to obtain upper and lower bounds on the minimum weight design of three-dimensional structures. The effect of body forces is included. Radially symmetric plane stress and plate bending problems are solved as examples.

F. DiMaggio, USA

2126. Banerjee, K. K., Continuity in precast reinforced concrete, *J. Technol.* **1,** 2, 123–145, Dec. 1956.

Points of weakness of a structure constructed of precast reinforced-concrete units (ordinary reinforced or prestressed) are the joints. The efficiencies of some of the common types of joints were determined from experiments conducted on two model slabs, constructed of precast reinforced-concrete units with both longitudinal and transverse joints. The variables in the tests were span-width ratio of slab, types of transverse joint, and types of longitudinal joint.

Though full continuity may be achieved through a joint over a support, it is difficult to obtain a perfect longitudinal joint. Experiments show that even the presence of steel across the latter type of joint does not materially help in resisting transverse moments at small loads, although the steel is certainly beneficial and therefore a necessity at loads near failure of the slab. A strong mortar key is capable of complete shear transfer across a longitudinal joint. This fact alone is enough to cause distribution of the applied load to other parts of the slab away from the point of application of the load. However, the behavior of such an anisotropic slab is inferior to that of a monolithic slab, but with more substantial research it will be possible to admit and allow some distribution of load in bridge or floor slabs constructed of precast concrete unit. From author's summary

2127. Mavis, F. T., and Greaves, M. J., Destructive impulse loading of reinforced concrete beams, *J. Amer. Concr. Inst.* **29,** 3, 233–252, Sept. 1957.

Reinforced-concrete beams, identical except for grade of reinforcement, were tested by pairs under destructive impulse loads in a unique spring-powered testing machine. Data from each dynamic test were filmed by a high-speed motion picture camera which superimposed continuous oscilloscope records of load and reaction, and photographs of the beams at frequency of 1000 pictures a second. Data such as deflection of beams, crack formation, and time intervals, were also recorded on the motion picture film for repeated projection, microscopic frame-by-frame study, and analysis.

Typical tests are detailed in this paper and dynamic behavior phases are identified and interpreted. Differences in behavior of beams under dynamic and static loadings are discussed further under headings of crack pattern and "whiplash," shear distribution and bond failure, steel strain and energy absorption. Bibliography lists 116 pertinent references.

From authors' summary

2128. Whitney, C. S., Ultimate shear strength of reinforced concrete flat slabs, footings, beams, and frame members without shear reinforcement, *J. Amer. Concr. Inst.* **29,** 4, 265–298, Oct. 1957.

Review of current research data on ultimate load tests of reinforced concrete members failing in shear shows that the shear capacity is proportional to $Mu/d^2 \times (d/l)^{1/2}$ where MU is the ultimate moment capacity, d the effective depth, and l the shear span. Author discusses applicability to design of various types of members and discusses effects of bar spacing on these values.

I. A. Benjamin, USA

2129. Wright, J. H., and Dowman, R. D., Design notes for glass reinforced plastics, *Aircr. Engng.* **24,** 344, 319–326, Oct. 1957.

Reinforced plastics have been widely used in the aircraft industry over the past ten years, but their application is still treated

as something of a special field. The purpose of these notes is to introduce the subject to the drawing office and to set simply before the draughtsman another engineering material.

The use of plastics is not recommended for primary structure at present, due to insufficiency of test results, but for secondary structure they may offer advantages in robustness and noncorrodibility over light alloy, with increase in weight, and sometimes with less weight.

In complex shaped fairings, the ease of forming of reinforced plastics enables the component to be moulded as an integral structure, thus reducing fabrication and consequently costs. The reduction in the number of parts means less weight and the resulting structure is often intrinsically stronger. They also have many applications where their particular properties, such as electrical properties, noncorrodibility, acid resistance or high specific tensile strength, are desirable.

Typical applications for the material are summarized, together with reasons for their use. From authors' summary

2130. Bartlett, R. J., An ultimate-load, or load-factor, method of design, *Concr. constr. Engng.* **52,** 8, 279–287, Aug. 1957.

2131. Dorn, W. S., and Greenberg, H. J., Linear programming and plastic limit analysis of structures, *Quart. appl. Math.* **15,** 2, 155–167, July 1957.

The limit analysis of elastic-perfectly plastic structures is identified as a problem in linear programming. Three methods of solution are available: (1) Lemke's dual problem; (2) simplex problem; and (3) a bounded variables problem. The adaptation of the three methods for limit analysis are outlined, and a simple plane pin-connected truss is worked out as an illustrative problem.

M. Pei, USA

2132. Hodge, P. G., Jr., and Paul, B., Approximate yield conditions in dynamic plasticity, Proc. Third Midwestern Conf. on solid Mech., Univ. of Mich., Apr. 1957, 29–47.

Paper is concerned with the important and novel problem of determining the collapse load of a rigid-plastic structure under conditions of shock loading. Limit analysis, which gives rigorous upper and lower bounds for static collapse loads, is not applicable. Authors proceed by solving a simple representative case (circular cylindrical shell loaded by uniform pressure pulse) so as to gain insight into the general nature of the problem. Solutions found for two different approximate yield conditions are adjusted so as to give same static collapse load; discrepancies in deformation and energy absorption are then of the order of 5%. Authors judge that this is a tolerable level of uncertainty, since dynamic yield stresses are dependent on strain rate and not exactly known.

F. C. Roesler, England

2133. Driscoll, G. C., Jr., and Beedle, L. S., Plastic behavior of structural members and frames, *Welding J.* **36,** 6, 275s–286s, June 1957.

Plastic design makes available to structural engineers a new design concept based on the maximum strength of structural steel as revealed by analysis of its plastic rather than elastic behavior under load. This report describes a comprehensive series of demonstration tests which were performed to illustrate the plastic behavior of basic structural members and frames. The results of the tests gave good agreement with the simple theory on which plastic design is based.

Flexure and buckling tests were made on simple beams, a flexure test was made on a continuous beam, and short columns were subjected to combined bending plus axial load. A test was made on a full-size welded connection of the type found in industrial buildings. Also, a complete gabled portal frame was tested to its ultimate load.

The results of these and many other tests of similar types lend the most convincing arguments that the maximum strength of structures may be predicted with sufficient accuracy to allow plastic design to be used with safety and confidence.

From authors' summary

2134. Wong, R. E., How-to-control charts for rapid weight-strength analysis of pressure vessels, *Prod. Engng.* **28,** 14, 95–98, Oct. 1957.

2135. Eby, R. E., Design criteria for glued laminated lumber, Amer. Soc. Agric. Engrs., Chicago, Ill., Dec. 1957. Pap. 57–568.

A summary of basic design information, particularly as applicable to glued laminated farm structures, is presented by one of the leaders in the field of laminated construction.

E. G. Stern, USA

2136. Doyle, D. V., Diaphragm action of diagonally sheathed wood panels, *U. S. Dept. Agric., Forest Prod. Lab. Rep.* no. 2082, 40 pp., Nov. 1957.

2137. Stern, E. G., Building diaphragms, *Military Engr.* **50,** 333, p. 50, Jan.-Feb. 1958.

Framed structures can be strengthened considerably by diaphragms without any increase in the cost of construction. For this reason, attention should be given to the application of diaphragms in residential, industrial, and military construction.

From author's summary

2138. Johnston, G. W., Factors affecting the field length of STOL aircraft, *AGARD Publications, Rep.* 81, 15 pp. + vi + 4 appendixes, Aug. 1956.

This note describes qualitatively some of the consequences of extending existing short field aircraft to the STOL class. It is concerned only with the performance implication as reflected by the requirement of operating the aircraft from a 500-ft field. For this note STOL aircraft are defined as those which can land or take-off over a 50-ft obstacle in 500 feet.

From author's summary

2139. Duncan, W. G., A study toward a system of classification of unprepared landing areas, *AGARD Publications, Rep.* 89, 6 pp. + iv, Aug. 1956.

"The ability to operate from unprepared areas" is a requirement for aircraft which has many different meanings to many different people. Aside from the one fact an "unprepared area" is one which is not prepared, not many other details as to its description can be readily agreed upon.

In an effort to create a system, or a method, for describing any unprepared area (which system can be used to specify the extent of the unpreparedness, as it were, and thus provide a link or communication between aircraft requirements people and aircraft designers), the Air Research and Development Command, U.S.A.F., undertook a study toward a method of classifying unprepared landing areas.

Preliminary results show the problem susceptible to solution and also indicate several further study areas which should be undertaken. From author's summary

2140. Smiley, R. F., and Horne, W. B., Mechanical properties of pneumatic tires with special reference to modern aircraft tires, *NACA TN* 4110, 166 pp., Jan. 1958.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 1877, 2000, 2004, 2009, 2035, 2061, 2066, 2073, 2097, 2119, 2132, 2133, 2183, 2394)

2141. Venkatraman, V., Solutions of some problems in steady creep, Polyt. Inst. Brooklyn., Aero. Lab. Rep. 401, 106 pp. + 38 figs., July 1957.

Paper forms readable introduction to behavior of structures in secondary stage of creep, including physical and technical aspects and giving a number of new solutions to special problems. Starting with simple properties in uniaxial tension and in particular from Norton's power law, author continues with applications to trusses, beams and frames. Exact as well as approximate methods, based on Hoff's elastic analog and corresponding minimum principles of nonlinear elasticity, are used, although proofs of the latter are only roughly hinted at. Two- and three-dimensional secondary creep is also treated in a similar manner. Special problems such as plane strain with rotational symmetry, torsion of prismatic bars whose cross sections are regular polygons and circular plates, uniformly loaded, are treated more in detail, and results of numerical calculations are reported. Bibliography contains 41 references. One serious misprint is noted: In Eq. (1.1) the power expression kt should be a factor $\exp(kt)$.

F. K. G. Odqvist, Sweden

2142. Isaksson, A., Methods in creep testing (in Swedish), Roy. Inst. Technol., Inst. of Strength of Material, Stockholm, no. 119, 24 pp., June 1957.

2143. Rzhanitsyn, A. R., Analysis of the bases of the general theory on creep (in Russian), Issledovanie prochnosti, plastichnosti i polzuchesti stroit. materialov, Moscow, 1955, 33–44; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8515.

The results of the investigation on the theory of creep on the basis of the integral equations of Vol'terra, carried out in his own time by the author, are submitted.

M. I. Rozovskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2144. Tranin, I. I., Evaluation of turbine disks in regard to creep by the method of elastic solutions (in Russian), Vopr. metalloved. kotloturbinnykh materialov., Moscow, Mashgiz, 1955, 104–121; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8519.

A method is demonstrated, without the use of transportation to source of origin, for calculating creep in rotating disks [see Yu. N. Rabotnov. *Izv. Akad. Nauk SSSR, Otd. tekh. Nauk* no. 6, 1948]. An example is given for the calculation of a disk of constant thickness without a central hole.

A. G. Kostyuk

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2145. Bodine, E. G., Carlson, R. L., and Manning, G. K., Creep deformation patterns of joints under bearing and tensile loads, *NACA TN* 4138, 36 pp., Dec. 1957.

The interaction of bearing and tensile loads on the creep behavior of joints was studied. A specimen was designed for this study which possessed some of the general features of pin and rivet joint connections and an apparatus was constructed to apply both bearing and tensile loads to the joint model. Deformation measurements were made by use of a photogrid printed on the joint model.

From authors' summary

2146. Hopkins, I. L., and Hamming, R. W., On creep and relaxation, *J. appl. Phys.* **28,** 8, 906–909, Aug. 1957.

The creep function for the National Bureau of Standards polyisobutylene at 25 C is calculated from the relaxation function, using the integral equation connecting them. The calculated function is shown to be correct in its initial slope, to satisfy the inequality $\varphi(t)\psi(t) \leq 1$ throughout, and to approach satisfactorily the independently determined asymptote.

From authors' summary

2147. Neville, A. M., The measurement of creep of mortar under fully controlled conditions, *Mag. Concr. Res.* **9,** 25, 9–12, Mar. 1957.

It is suggested that the chemical composition of cement is a vital factor in creep of mortar. A new loading apparatus for the measurement of creep is described and results of tests with three different cements are presented.

From author's summary

2148. Kunin, N. F., and Svirsky, M. S., The plastic flow of metals at varying temperatures (in Russian), *Trudi Chelyabinsk. in-ta mekhaniz. i elektrifik. s.kh.* no. 5, 112–117, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6909.

Integrating the stress differential (for isothermal and unaccelerated plastic deformation)

$$d\sigma = \left(b - \frac{a}{v}\right)\sigma\, dz$$

in which the coefficient of strain-hardening b and the coefficient of recovery a are expressed in terms of the deformation ϵ:

$$b = \frac{1}{\epsilon};\ a = \frac{1}{r_0}\exp\left[-\frac{U_0 - U_1(\epsilon - \epsilon_0)}{KT}\right]$$

(U = energy of activation), authors arrive at the relationship

$$\sigma = A\epsilon_e^{-mT}$$

which is confirmed by the experimental results quoted, both the authors' own, and others in the literature.

S. A. Shesterikov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2149. Naghdi, P. M., Essenburg, F., Koff, W., An experimental study of initial and subsequent yield surfaces in plasticity, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-37, 9 pp.

Experimental results for twenty-five tubular specimens of a 24ST-4 aluminum alloy, subjected to combined torsion-tension-reversed torsion, are reported in a study of the initial and two subsequent yield surfaces covering the first and the fourth quadrant of the axial stress-shear stress plane. Results are also given for two additional specimens subjected to tension followed by torsion, in order to compare the values of the initial shear modulus at the initiation of twist with the elastic shear modulus.

From authors' summary

2150. Green, A. P., and Hundy, B. B., Plastic yielding of I-beams: Shear loading effects analysed, *Engineering* **184,** 4767, 74–76, July 1957.

Paper is concerned with the initial plastic yielding of an I-beam due to the combined effect of bending moment and shear force. Various theoretical relations are reviewed which correct the simple theory of pure bending by taking into account the effect of a shear force. New experiments are described in which both the loads and plastic deformation at yielding are investigated, using model mild-steel I-beams. This work confirms and supplements experiments by other workers. It is concluded that of the existing formulas those suggested by Heyman and Dutton are the most useful for design purposes.

From authors' summary by A. Phillips, USA

2151. Hodge, P. G., Jr., A general theory of piecewise linear plasticity based on maximum shear, *J. Mech. Phys. Solids* **5,** 4, 242-260, 1957.

This is a continuation of the methods published so fully by the Brown University group of plasticians and deals with just the maximum shear stress yield condition, the stress-velocity *vs.* strain-velocity relationship, and the principles of minimum potential and complementary energy. "It is shown that the most general piecewise linear theory depends upon five material constants... Whether or not the theory is accurate is beyond the scope of the paper." This general theory embraces the particular theories of author's colleagues. Further, "... the theory can be useful only in those problems in which the principal directions of stress and strain coincide and remain fixed throughout the loading process... Even within this limitation of application, there is no assurance that any real material will satisfy the conditions of the theory."

Author's frankness is commendable on the abstractness and severe limitations of the theory. Reviewer notes further that a "general theory" is deficient unless it takes account of the physical continuity of the plastic body by compatibility conditions on the strain-velocities (or strains) which plasticians (and fluids mechanicians) have overlooked [See reviewer's "Analysis of deformation," vol. III; Fluidity, art. VI, 5]. Yet again, stress-velocity, strain-velocity laws cannot be stated arbitrarily without having in view such mathematical requirements as invariance with reorientation of axes. [See op. cit. vol. I: Mathematical Theory, arts. II, 9, IV, 10, with regard to elasticity.]

K. H. Swainger, England

2152. Hill, R., On the problem of uniqueness in the theory of a rigid-plastic solid. IV, *J. Mech. Phys. Solids* **5,** 4, 302-307, 1957.

In the preceding paper of this series, a sufficient condition was obtained for the uniqueness of a continuous velocity field in a properly set boundary-value problem for a rigid, work-hardening solid, when the changes in geometry are taken into consideration. In the present paper, the unique velocity field is characterized by a minimum property. W. Prager, USA

2153. Sawaragi, Y., and Tokumaru, H., On the nonlinear flow of a visco-plastic-elastic material, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 209-212.

2154. Shimanskii, Yu. A., Practical theory of the plasticity and strength of steel (in Russian), Sb. statei po sudostroeniyu, Leningrad, Sudopromgiz, 1954, 341-394; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8486.

A theory of plasticity is propounded, the basic idea of which consists in the conception that the principal elongations are calculated with the assistance of certain values (particular deformations) which are found in the diagrams of tension-compression. The reasons for the relationships put forward remain somewhat obscure. The propositions put forward by the author are not compared with existing theories, nor is the experimental.

T. N. Vasitsyna

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Failure, Mechanics of Solid State

(See Revs. 1877, 2059, 2168)

Mechanical Properties of Specific Materials

(See Revs. 2129, 2135, 2136, 2147, 2154, 2319)

Plasticity, Forming and Cutting

(See Revs. 1943, 1952, 2009)

Hydraulics; Cavitation; Transport

(See also 1852, 1937, 1940, 2021, 2181)

Book—2155. Zavialov, K. D., and Proskuriakov, A. K., edited by, Problems of construction of hydrologic instruments (in Russian), Trudĭ Gos. Gidrolog. Inst. no. 64, Leningrad, Gidrometeoizdat, 1957, 57 pp. $0.50.

In this series of articles P. N. Burtsev explains his efforts to construct a current meter with component runner of several blades (however with little success) and another meter compensated for friction. K. D. Zavialov presents his stage transmitter and linmigraph. A. M. Dimaksian summarizes radioactive isotope application in hydrologic research. P. N. Burtsev and B. Iu. Baier study stability of rating curves and time for rerating. G. M. Rimmar presents statistical data on performance of 754 current meters of type Zh-3. S. Kolupaila, USA

Book—2156. Chebotarev, V. I., and Skuie, A. R., Hydrometrical constructions [Gidrometricheskie soorusheniia], Leningrad, Gidrometeoizdat, 1954, 371 pp. $1.60

Book deals with river discharge measurements: gages, weirs, bridges, cableways, boots, artificial control. Materials, works, rating and maintenance are explained. Book is for use in technical schools and can be of interest for hydrographers and for hydraulic engineers. S. Kolupaila, USA

Book—2157. Miliukov, P. I., edited by, Problems of forecasts and evaluations of spring and summer runoff (in Russian), Trudĭ Tsentr. Inst. Prognozov. no. 50, Leningrad, Gidrometeoizdat, 1957, 168 pp. $1.50.

Series of articles by 7 authors on methods of forecasts for flat lands in Russia and Siberia. They are of great interest for hydrologists. S. Kolupaila, USA

Book—2158. Sokolovskii, D. L., edited by, Problems of runoff formation and methods for design (in Russian), Trudĭ Gos. Gidrolog. Inst. no. 61, Leningrad, Gidrometeoizdat, 1957, 307 pp. $2.40.

A series of articles by 12 authors on derivation of runoff from rainfall. D. L. Sokolovskii extends the American "unitgraph" method. V. G. Andreianov analyzes theoretical runoff variation during months and seasons. M. I. Gurevich discusses elementary runoff and genetic runoff formula. G. A. Alekseiev gives approximate method of statistical computation. A. P. Bochkov forecasts influence of culture of Hwangho River regime in China. S. N. Bogoliubov writes on ground-water influence on spring flow and temporary creeks. N. F. Panova presents methods of construction of runoff diagrams for flat lands in Russia, with numerous data tables. L. P. Semlianskaia explains determination of maximum discharge in small rivers of Russian bushes and steppes. M. I. Baiusheva discusses methods of maximum flow determination for Kazakhstan. D. D. Kvasov and E. E. Zuber-Ianikun apply variation curves to runoff determination. I. M. Georgievskiĭ studies influence of forest density on maximum height of spring flood.

This is a collection of serious contributions of Russian hydrologists to the river runoff forecasts. S. Kolupaila, USA

Book—2159. Popov, E. G., Hydrological forecasts [Gidrologicheskie prognozy], Leningrad, Gidrometeoizdat, 1957, 460 pp. $1.50.

This is a textbook for technical schools, of great interest for hydrologists. Its chapters: Hydrology and importance of fore-

casts. Available data on water resources. Amount of basic data for forecasts. Fundamentals for elaboration and evaluation for forecasts. Surface runoff and laws of its formation. Short-term forecasts based on propagation time. Construction of runoff diagrams. Long-term forecasts for spring flood in flat lands. Runoff forecast in mountains. Low water forecasts. Forcast of ice regime—freezing and breaking time. Hydrological information for water control administration. Many selected examples and diagrams illustrate the book. S. Kolupaila, USA

Book—2160. Dzunkovskii, N. N., edited by, Introduction to hydraulic engineering [Vvedenie v gidrotekhniku], Moscow, Gos. Izdat. Stroit. Arkhit., 1955, 302 pp. $1.10.

A textbook for freshmen in Russian schools for hydraulic engineers, compiled by several authors, among them E. V. Lleniak, N. P. Rozanov, F. F. Gubin, N. N. Abramov. Contents: materials, hydrology, dams, power development, inland waterways, seaports, irrigation and drainage, water supply, fish conservation, multiple use of rivers and lakes. Water investigations. Construction methods. S. Kolupaila, USA

2161. Gardel, A., Stability of surge tanks: influence of the operation of upstream equipment on small oscillations in case of automatic control (in French), *Bull. tech. Suisse rom.* **83,** 20, 331-341, Sept. 1957.

Paper can be considered as an appendix to author's recent volume [AMR **10** (1957), Rev. 461]. It studies the influence upon the small oscillations in a surge tank of causes situated downstream and neglected by the original Thoma's theory: velocity head at the foot of the surge tank, loss of head in the forced conduit, water hammer, variation of turbine efficiency, connection with the electric net. A general formula is found which gives the horizontal section of the tank as a function of the desired damping of the oscillations, taking into account all known factors. It is found that velocity head and net connection have a stabilizing effect, contrary to loss of head in the pipe and variation of efficiency; water hammer can be neglected. The formula is represented in a useful graph. A numerical example is given.
D. Citrini, Italy

2162. Jaeger, C., Contribution to the stability theory of systems of surge tanks, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-65, 6 pp.

After a short historical review of the results obtained by many authors, paper studies again the stability of two surge tanks in series on the same tunnel when governing at constant output.

The surge equations with relative values use only six parameters; this number gets down to five with a uniform pressure tunnel, the only case studied in the paper.

The discussion of stability conditions allows calculation of the area of surge tanks according to their relative position and to head losses in the different parts along the pressure tunnel.

Conclusions of author are:

(1) The area of downstream tank must be larger than Thoma's area; so, generally avoid introducing secondary water-streams by shafts into the downstream part of pressure tunnel.

(2) Nevertheless, even with a downstream tank area lesser than Thoma's, stability may be obtained by increasing (always an important increase indeed) the area of upstream tank. However, such a solution is never economic.

(3) For a short pressure tunnel, the area of upstream surge tank must be most important when near the reservoir, even when the area of downstream surge tank is much greater than Thoma's area.

This is a new presentation of a problem which has already been studied. L. Escande, France

2163. Parmakian, J., One-way surge tanks for pumping plants, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-25, 6 pp.

One-way low-level surge tanks may be used for the control of water hammer at pumping plants where water-column separation occurs in the discharge line subsequent to a power failure at the pump motors. This paper describes the characteristics of these tanks and also includes a typical graphical water-hammer solution of the problem. From author's summary

2164. Kursin, S. A., The resistance of a tubular water outlet (in Russian), *Nauch. zap. in-ta mashinoved i avtomatiki Akad. Nauk USSR* **5,** 256-258, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7461.

From laboratory tests on a model discharge pipe, data are given for the pressure distribution along a discharge pipe and on the values of the coefficient resistance. P. G. Kiselev
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2165. Schroder, R., Investigation of rapidly varied flow in open channels (in German), *Mitt. Inst. Wasserbau* no. 48, 1957, 109 pp. + 9 tables.

In this thesis author revises the fundamental principles of hydraulics—the energy and impulse-momentum, mostly following ideas of Ch. Jaeger ["Engineering fluid mechanics"]. By introducing correction factors for both velocities and pressures he tried to prove that both these principles can be applied in conditions of discontinuous flow. Elaborate laboratory tests were performed in order to confirm statements of author. The results were applied for determination of stilling pool dimensions below a spillway of a dam.

It is regretted that this valuable dissertation was not printed in usual typographic form. S. Kolupaila, USA

2166. Basilevich, A. I., Movement of water in loose stone embankments (in Russian), *Nauch. zap. L'vovsk. politekhn. in-ta,* no. 31, 75-88, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8401.

On the bases of known relationships, author investigates the calculations involved in a stone dam affiliated with the quadratic rule of filtration. G. K. Mikhailov
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2167. Agostinelli, A., and Salemann, V., Prediction of flashing water flow through fine annular clearances, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-78, 5 pp.

The flow of a flashing mixture of water and steam through smooth annuli of fine clearance has been investigated experimentally. Test data have been obtained with inlet conditions to 600 F and 3000 psi. Critical conditions have been observed experimentally up to these temperatures and pressures. With the assumption that the flashing mixture is homogeneous a method for the prediction of flow and two-phase pressure drop is presented and discussed. From authors' summary

2168. Lichtman, J. Z., Kallas, D. H., Chatten, C. K., and Cochran, E. P., Jr., Study of damaging effects of cavitation erosion to ships' underwater structures, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-156, 24 pp.

The effects of fluid cavitation and cavitation-bubble collapse on a guiding surface have been investigated using two water tunnels, a magnetostrictive-transducer apparatus, a piezoelectric-transducer apparatus, and a rotating-disk apparatus. Studies of the mechanism of damage to a surface and its relationship to change in fluid pressure and stream velocity were made. As a result of

these studies and examination of numerous ships in service, authors have arrived at certain conclusions concerning the mechanism of damage to underwater appendages. Although fluid cavitation may occur adjacent to many underwater appendages of vessels at normal operating speeds, there is considerable evidence that the areas in which cavity collapse is the primary cause of damage are restricted to propellers. Damage to ships' struts, rudders, and other appendages is shown to be primarily corrosive in nature, aggravated by mechanical scouring action. Based on these conclusions, shipbuilding activities may take corrective action to protect ships' appendages against chemical damage and need not be concerned with protection of these structures against primarily impact-fatigue erosion associated with cavity collapse at higher stream velocities. From authors' summary

2169. Bohn, L., Sound spectra and acoustic pressure distribution for cavitation (in French), *Acustica* **7,** 4, 201–216, 1957.

The pressures and sound spectra for cavitation set up in the focus of a transducer array of 15 kc/s are measured with a magneto-strictive probe.

In weak cavitation, bubbles are formed and set in oscillation at their natural frequencies. They stabilize themselves with a definite radius (depending on air content), which can lie below that for resonance with the source, and burst under strong excitation. In hard cavitation, strong pressure pulses are set up, which mainly influence the noise spectrum.

Other matters considered are relationship between pulse and excitation; pulse form and duration; statistical fluctuations from the mean position. From author's summary

2170. Mundry, E., and Guth, W., Movie pictures of vibrational cavitation (in French), *Acustica* **7,** 4, 241–250, 1957.

Cavitation bubbles are produced from a nickel transducer of frequency 2.5 kc/s and photographed at 12,500 to 105,000 frames/sec. In aerated water and moderate sound fields, bubbles are observed to vibrate in a mode indicating a combination of nonlinear forced vibration and sudden excitation at the natural frequency. In stronger fields both in aerated and degassed water a large number of tiny bubbles, which almost disappear during the time-period of one oscillation, are seen. The strong shock waves accompanying this phenomenon are photographed in a schlieren system.

From authors' summary

2171. Westmoreland, J. C., Prediction of the pressure loss and density factors for two-phase annular flow with or without heat generation, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-50, 18 pp.

A simple analysis is presented for predicting pressure loss and density factors for two-phase, one-component annular flow with and without heat generation. All four combinations of laminar and turbulent flow in both the annulus and core are considered. The analysis is based on assumed velocity profiles and matching velocity and shear stress at the liquid-vapor interface. The theory is found to compare favorably with experimental results on both vertical and horizontal sections. The application of the theory to natural circulation steam generators is also presented.

From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 2161, 2184, 2235, 2237, 2242, 2254, 2255, 2256, 2261, 2264, 2275, 2296, 2306, 2315, 2340, 2341, 2358, 2375)

2172. Nakagawa, Y., Experiments on the instability of a layer of mercury heated from below and subject to the simultaneous action of a magnetic field and rotation, *J. roy. Soc. Lond.* **242,** 1228, 81–88, Oct. 1957.

A pool of mercury placed in a Pyrex glass container was heated electrically from below and was rotated in the magnetic field of cyclotron magnet. Thermocouple readings were made but no flow measurements were taken. Results are compared with Chandrasekhar's theoretical predictions.

L. S. G. Kovasznay, USA

2173. Viswanadha Sarma, L. V. K., Rotational flow of a liquid past a regular polygonal cylinder, *Proc. Indian Acad. Sci. (A)* **45,** 3, 224–231, Sept. 1957.

Paper deals with parallel flow with uniform shear past a regular polygon symmetrically placed with respect to the direction of flow. The condition on the orientation of the polygon is not stated but implied. Author finds that the polygon is urged toward the wall (the line of zero velocity) and states that this is independent of the number of sides n of the polygon, provided that it is inscribed in a circle of radius d. This statement is misleading because d is a function of n. d is not worked out but reviewer finds that $d = (2/n)B(2/n, 1 - 1/n)$, where B is the beta function. Confusion arises owing to the omission of a representative length in the analysis, which is extended to a hypotrochoidal section, and numerical results are given for a three-cusped and four-cusped hypocycloid. The semidimensional nature of these results makes their interpretation difficult.

Reviewer notes that a circular cylinder is urged *away* from the wall. He suspects a mistake in the analysis but is unable to find it. J. C. Cooke, England

2174. Kiselev, A. A., Unsteady flow of viscous incompressible fluid in a bounded three-dimensional space (in Russian), *Dokladi Akad. Nauk SSSR (N. S.)* **106,** 1, 27–30, Jan. 1956.

Two theorems of existence are proved for title problem, allowing the solutions to be of the generalized type in the sense of Sobolev (or, following L. Schwartz, distributions).

G. Moretti, Argentina

2175. Hahn, E. Yu., Loss of head and dissipation in the flow of an incompressible fluid (in Russian), *Sb. nauch. tr. Kuibyshevsk. industr. in-ta* no. 5, 181–192, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8217.

An attempt is described to formulate the conception of loss of mechanical energy in a fluid flow, as distinct from a loss of head. For this purpose, author has had recourse to the conceptions and conclusions of M.A. Velikanov ["The dynamics of channel flows," Gidrometeoizdat, 1946], some inaccuracies being allowed. For instance, on page 185, lines 8 and 9 are incorrectly written; on p. 186, author identifies a point with a volume and attributes thereto the presence of work of internal energy.

M. A. Mostkov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2176. Krzyblocki, M. Z. v., On the stream functions in non-steady three-dimensional flow, *J. aero. Sci.* **25,** 1, p. 67 (Readers' Forum), Jan. 1958.

2177. Black, J., A note on the mixing process in the flow induced by a high velocity air jet, *J. roy. aero. Soc.* **61,** 561, 631–633 (Tech. Notes), Sept. 1957.

2178. Eckert, E. R. G., and Irvine, T. F., Jr., Incompressible friction factor, transition and hydrodynamic entrance-length studies of ducts with triangular and rectangular cross sections, Proc. Fifth Midwestern Conf. Fluid Mech., Univ. of Mich., Apr. 1957, 122–145.

Triangular duct has an isoceles triangle cross section (base 0.38 in., apex angle, 23°); it was investigated with a rounded and a sharp entrance. Rectangular duct has a rounded entrance with

cross section dimensions 1.053 in. × 0.498 in. (breath-to-depth ratio = 3). The range of Reynolds numbers is 10^3 to 2.14^4, the air flowing with moderate subsonic velocities.

Results in the triangular duct with rounded entrance show that intake length increases from 20 d_h for Re = 140 to 140 d_h for Re = 4950 ($d_h = 4A/C$, A cross sectional area; C circumference). With sharp entrance section, this intake length is slightly different.

Friction factors for developed flow in the laminar range follow Poiseuille's law, K/Re (K constant depending of the form of the cross section; Re Reynolds number based on the average velocity and the length d_h). Curves are reproduced for the values of K for rectangular duct, triangular duct, circular sector, elliptic duct, annular duct. In the turbulent range, Blasius' law, $0.316/Re^{0.25}$ always described the experimental results satisfactorily, above Re = 7000.

Transition occurs suddenly at Re = 6000 for the triangular duct with rounded entrance and at Re = 5000 for the rectangular duct. For triangular duct with sharp entrance, one can distinguish a lower critical Re (1500) at which departure from the laminar relation occurs and an upper critical Re (2000) at which turbulent friction is established. E. Brun, France

2179. Rouggignac, C., Performance of compressor blade grids having various cambers and aspect ratios (in French), *ONERA NT* 39, 70 pp., 1957.

Paper reports tests of three grids gaving small, average, and large blade cambers. Variations of angle of attack, pitch-chord ratio, and aspect ratio were also tested, though range was not great. Conclusions: (1) For blades of small camber (small pressure increase), pressure distribution is quite uniform, with few surface disturbances and little decrease of effective flow area. Usual coefficients of performance remain constant for given shape and apply equally to blades assembled in working rotor. Results obtained at low speeds can be extrapolated to higher speeds by approximate compressibility corrections. (2) For blades of large camber, pressure distribution is nonuniform, with peak at midblade. Boundary-layer thickness increases rapidly, with consequent flow separation and decrease of effective area. Characteristics are not similar to those of blades with small camber, nor to those of blades assembled in working rotor, nor consistent among themselves, unless boundary layer is removed by use of porous blades. Such removal is difficult and process cannot always be relied unon. (3) In general, small aspect ratios increase loss coefficients but reduce angular deviations. Unless provision is made for boundary-layer removal, aspect ratios less than 1.5 should be avoided. Aspect ratios greater than 2 give poor pressure distributions and irregular angular deviations.

Reviewer believes data given are useful contribution to store of experimental data which must be built up to insure more consistent designing of compressor blades. C. W. Smith, USA

2180. Garabedian, P. R., On steady-state bubbles generated by Taylor instability, *Proc. roy. Soc. Lond.* (*A*) **241,** 1226, 423–431, Aug. 1957.

A theory of the steady motion of a long bubble rising through an infinite plane vertical tube of liquid is presented. It is shown that, contrary to current belief, the flow is not uniquely determined by the width b of the tube and the acceleration of gravity g alone, but that the speed U of the bubble can also be prescribed. However, a criterion of stability singles out the unique physically significant flow of this type as the one which maximizes the velocity of the bubble. With the aid of a difference-differential equation derived from the free-boundary condition, the Froude number $U/(gb)^{\frac{1}{2}}$ for this latter case is estimated to exceed 0.2363, a value slightly higher than that indicated by earlier work on the problem. From author's summary by L. Talbot, USA

2181. Silberman, E., Production of bubbles by the disintegration of gas jets in liquid, Proc. Fifth Midwestern Conf. Fluid Mech., Univ. of Michigan, Apr. 1957, 263–284.

A gas jet issuing from a nozzle into liquid breaks up into discrete bubbles because of the instability of the jet. The bubbles may be of various sizes but the largest ones correspond to the volume of gas pinched off from the jet by a wave length of the unstable disturbance. A theory is presented to predict the largest bubbles, with experimental confirmation obtained in liquid moving relative to the orifices that produced the jets. Size distribution of bubbles below the largest can be obtained only by experiment. The equations developed show that, when the liquid moves relative to the orifices, the maximum bubble diameter equals 2.4 times the square root of gas-flow rate per jet divided by the liquid velocity. When there is no relative motion, the diameter is proportional to the 0.4 power of the gas-flow rate. The bubble diameter is independent of gas and liquid properties and of orifice characteristics, as long as the gas issues as a jet from each orifice. By applying the relations developed to systems of gas orifices discharging into moving liquid, the gas-flow rate and liquid velocity may be selected so that bubbles may be produced of any desired maximum diameter, from several inches to a few thousandths of an inch.

Test equipment is described and illustrated; flash photographs of bubbles are shown; charts of bubble-size distribution are shown as function of rate of air flow divided by water-flow velocity.
K. J. DeJuhasz, Germany

2182. Guth, W., Nonlinear oscillation of air bubbles in water (in German), *Acustica* **6,** 6, 532–538, 1956.

The vibration characteristics of bubbles excited to large amplitudes in water are investigated. Both in free and forced vibration, the changes of frequency, mean bubble radius and, especially, the mean internal air pressure are calculated in their dependence on amplitude. Approximate solutions for the nonlinear vibration are calculated in both cases. The resonance curves under forced vibration are calculated. Finally, a plausible explanation of the incidence of the often observed subharmonics is given.
From author's summary by P. Eisenberg, USA

2183. Saffman, P. G., On the motion of small spheroidal particles in a viscous liquid, *J. Fluid Mech.* **1,** 5, 540–553, Nov. 1956.

Jeffery's hypothesis that small spheroidal particles suspended in a liquid with uniform shear tend to take up preferential orbits, regardless of initial conditions, is discussed in this paper. Author tries to give a theoretical support to this hypothesis by (a) evaluating the effects of the terms neglected in Jeffery's solution of the equations of motion; (b) taking into consideration non-Newtonian properties of the liquid, that is, the possibility that the stress tensor be not linearly related to the rate-of-strain tensor. The deductions of the theoretical treatment are compared with experimental observations of the author and from other sources.

In spite of the analytical and physical difficulties involved, which in a few instances require the introduction of questionable assumptions, author succeeds in showing that both the inertia of the liquid and its non-Newtonian properties can account for the tendency of the particles towards preferred orientations. However, the latter effect must be overwhelming, as the comparison with the experimental results shows.

Finally, some consideration is given to the problem of the suspension of many particles and to possible applications to it of statistical and detailed mechanics.
P. L. Romita, Italy

2184. Eastaway, K. G., A novel mechanism for gas-liquid mixing, *Chem. Process Engng.* **37,** 397–398, Nov. 1956.

A high-pressure hydrogenation autoclave of 500-gal capacity, suitable for 200 psi pressure at 250 C temperature, is described

and illustrated. The autoclave is partially filled with liquid, and above that with hydrogen. Liquid is taken from the bottom of the autoclave and pressed, with a centrifugal pump, through a conical nozzle into the hydrogen space. Here the issuing liquid jet entrains hydrogen in the form of bubbles, and then enters the liquid. Thereby an intense agitation and thorough mixing is attained which promotes the reaction. K. J. De Juhasz, Germany

2185. Lewis, J. P., and Ruggeri, R. S., Experimental droplet impingement on four bodies of revolution, *NACA TN* 4092, 61 pp., Dec. 1957.

Rate and area of cloud droplet impingement on four bodies of revolution were obtained experimentally in the NACA Lewis icing tunnel. Spheres, ellipsoidal forebodies of fineness ratio of 2.5 and 3.0, and a conical forebody of 30° included angle were studied at angles of attack of 0° and 6°, rotational speeds up to 1200 rpm, and an airspeed of 157 knots. Results are presented in the form of dimensionless impingement parameters in order to cover a wide range of flight and atmospheric conditions, and are compared with theoretically calculated impingement characteristics. Purpose of tests was to obtain data for the design and evaluation of icing protection equipment for aircraft components, and determination of surface requiring protection. Apparatus and test bodies are described and illustrated. Spray droplet size distribution is given in chart; volume-median droplet diameters ranged from about 11 to 19 microns. K. J. De Juhasz, Germany

2186. Ingebo, R. D., and Foster, H. H., Drop-size distribution for cross-current breakup of liquid jets in airstreams, *NACA TN* 4087, 36 pp., Oct. 1957.

Photographing and sampling techniques were combined to obtain drop-size data for ranges of injector, liquid, and airstream variables. The following empirical expressions correlated the ratio of volume-median diameter D_{50} to orifice diameter D_0 with Weber-Reynolds number ratio $D_{50}/D_0 = 3.9\,(We/Re)^{0.25}$ where $We = \sigma/\rho_s D_0 V_s^2$, $Re = D_0 V_s/\nu$, where σ and ν are surface tension and kinematic viscosity, respectively, of the liquid; and V_s and ρ_s are free-stream velocity and density, respectively, of the air. A drop-size distribution equation based on maximum observed drop diameter and Weber-Reynolds number ratio was also derived:

$$dR/dD = 10^6\,(We/Re)^{0.24}\,(D^5/D^5_{max})e^{-22.3\,(We/Re)^{0.4}\,D/D_{max}}$$

The test installation, comprising a high-speed camera capable of photographing microscopic droplets traveling at high velocity, and the sampling probe, is described and illustrated. A complete sample calculation of mean drop diameter is given. Derivation of dimensional analysis formula is carried out. Reference is made to the work of previous investigators: Rosin-Rammler, Nukiyama-Tanasawa, and Longwell. The atomization of liquid jets was investigated under conditions similar to those in ramjet engines and afterburners. K. J. De Juhasz, Germany

2187. Ranz, W. E., and Hofelt, C., Determining drop size distribution of a nozzle spray, *Indust. Engng. Chem.* **49,** 288–293, 1957.

Because a rapid and routine method is needed for measuring drop-size distributions in sprays, a rectangular jet impaction system was developed as a test apparatus for obtaining cumulative volumes versus drop sizes in sprays.

Inertial impaction theory was the basis for design of equipment and analysis of test data. A test stand, scaled to the order of 10 ft, was built to measure drop sizes of the order of 100 microns. The special flow system, test procedures, and experience with actual sprays from domestic oil burner nozzles are described. The impacter constructed for development tests gave a relative measure of spray drop sizes in the range of 60 to 90 microns. A larger apparatus can be designed for analyses of sizes up to 150 microns. The apparatus consisted of the liquid flow circuit, the slot system for sectioning and sampling of the spray, horizontal entrainment channel and nozzle, impact plate, casing, separator, orifice meter, air exhaust system, and various drainage channels and tubes for collecting spray liquid. The experimental procudure is described. Validity of "characteristic diameter" concept is analyzed mathematically. K. J. De Juhasz, Germany

2188. Siemes, W., and Kaufmann, J. F., Drop formation in liquids in nozzles at high rates of flow (in German), *Chem.-Ing.-Tech.* **29,** 32–38, 1957.

Drop formation at round, smooth-edged, vertical orifices, at medium and high flow rate is investigated. Size of drops, and characteristic quantities derived from it, were determined as functions of rate of flow, orifice radius, and liquid characteristics of the continuous and the dispersed phase, in order to clarify phenomena in solvent-extraction and in liquid-liquid reactions in chemical processes. Five orifices, with diameters of 1,2,3,4 and 6 mm were used, the flow velocity was varied from 20 to 200cm/sec; the continuous-phase liquid was water and sugar solution, and the disperse phase liquids were gasoline, benzol, turpentine, and paraffin of various densities, surface tensions, and viscosities. Flash photography technique was used, and the photos were evaluated for drop-size distribution; the results are represented in drop-size spectrum curves, and in specific surface (total surface of drops divided by total volume) curves as functions of the various liquid properties. K. J. De Juhasz, Germany

2189. Fraser, R. P., Liquid fuel atomization, Sixth Symposium (International) on Combustion, Pittsburgh, Pa., Aug. 19–24, 1956, 687–701.

In liquid fuel combustion the object of the atomizer is to disintegrate the fuel into the smallest drops possible to increase the specific surface of the liquid and thus the rate of mixing and vaporization. The functions of the atomizer are to accelerate and disintegrate the liquid by the production of a liquid sheet from which threads and finally drops are produced, and also to disperse the resulting drops in a controlled pattern and direction. Author discusses classification of atomizers; effect of spraying atmosphere on drop size; table of viscosities for various liquids; drop size from pressure atomizer; atomization by means of a second fluid (twin-fluid atomizers); detailed diagrams of sprays issuing from vortex cup atomizers showing isobar lines; rotary atomizers. Of particular value is the concise analysis of previous researches on atomization, from Rayleigh's early work to present time.
K. J. De Juhasz, Germany

2190. Plockinger, F., Characteristic numbers of atomization (in German), *Maschinenb. u. Waermewirtsch.* **11,** 8, 217–220, 1956.

An attempt is made to find common theoretical basis for the characterization of atomizing nozzles. Author distinguishes two main types: I. Atomizers using purely a pressure in which the liquid is forced at high speed into quiescent air; II. atomizers using pressure air, in which the liquid itself is at rest while the atomizing air has high speed. Then the forces entering into the atomizing process are considered: friction, viscosity force, inertia force such as impact with a plate or impact of two jets, or centrifugal force. Finally, author distinguishes three basic kinds of drop formation: (a) drop emerging from a tube end, (b) disruption due to outside forces, (c) disintegration by wave formation. The characteristic numbers are derived on the basis of assuming one or the other kinds of forces having predominant influence, and using the methods of dimensional analysis. In general, nine kinds of dimensionless numbers are possible, but only a few have importance, in particular the Reynolds number, the Froude number, and the Weber number. K. J. De Juhasz, Germany

2191. Bezemer, C., and Schwarz, N., A new equation for the the size distribution of emulsion particles (in Dutch), *Kolloid Z.* **146,** 1/3, 145-151, 1956.

A new equation for describing the size distribution of emulsion particles is presented, termed the "Amsterdam Distribution Equation" (ADE), which is an exponential function having two parameters: the largest droplet diameter, and the size parameter (being the slope of the straight-line graph in a logarithmic diagram). The limits of applicability of this equation have been tested by comparing it with experimental data taken from work of previous experimenters as to: (a) a goodness of fit and (b) agreement as to average diameter.

Comparison is made also with two widely used particle-distribution equations, namely (a) that of Rosin and Rammler and (b) log-probability equation. Reference is made also to the Nukiyama-Tanasawa equation. It is found that the new ADE equation yields closer fit with the experimental data for emulsions than do previously proposed equations. In the discussion it has been pointed out that the Rosin-Rammler equation has been developed primarily for solid particles and not for emulsions. It is also pointed out that all proposed distributions have two maxima, which are probably due to two simple dispersions being present, produced by two different physical mechanisms, e.g., by atomization and condensation in case of liquid sprays.

K. J. De Juhasz, Germany

2192. Fraser, R. P., The important functions of the spray nozzle, *Commonwealth Phytopathological News, Kew, England,* **3,** 1, 3-6, Jan. 1957.

The spray nozzle or atomizer is a device to accelerate and disintegrate the liquid; first by producing a liquid sheet from which drops will be produced, and secondly by dispersing the resulting drops in a controlled pattern and direction. Spraying is a complex physical phenomenon because of: (a) the large number of dimensional variables in the atomizer nozzle itself; (b) the variation in physical properties of the liquid sprayed and in the hydraulics of the flow; (c) the changes in the ambient surroundings of the spray. Different applications call for different drop sizes, e. g., aerosols for space sprays require drop sizes from 1 to 30 microns, fungicidal sprays 100 microns, weed killers of 100 to 300 microns; long-distance spraying in orchards may require drop sizes of 1500 microns to reach the distance required. For each application a number of nozzle sizes and designs is required to obtain the desired effect. There is no universal nozzle for all purposes, though nozzles can be designed with interchangeable parts to satisfy different spraying requirements.

Flash photos are shown of sprays from accurately manufactured nozzles yielding uniform-size droplets and even distribution, and from damaged nozzles yielding uneven droplets and distribution. Also sprays of distilled water with normal surface tension, and of tap water with surface active agent admixture are shown, the latter having a wider angle and more rapid disintegration. Similar changes can be observed in spraying slurries containing solid materials. Much can be done for controlling drop size by manipulating the physical properties of the spray mixture.

K. J. De Juhasz, Germany

Compressible Flow, Gas Dynamics

(See also Revs. 1816, 2120, 2258, 2283, 2284, 2305, 2317, 2323, 2325, 2326, 2328, 2343, 2365)

2193. Tinling, B. E., and Lopez, A. E., The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. I-Effects of horizontal-tail location and size on the longitudinal characteristics, *NACA TN* 4041, 85 pp., July 1957.

An investigation has been conducted to determine the effects of horizontal-tail location and size on the longitudinal aerodynamic characteristics of an airplane model having a triangular wing. The wing had an aspect ratio of 3 and the NACA 0003.5-63 section in the streamwise direction. Two horizontal tails were tested which had areas of either 16.7 or 21.9% of the wing area. Each of the horizontal tails had an aspect ratio of 4, a taper ratio of 0.33, the NACA 0004-64 section, and no sweepback of the 50% chord line. Tests were conducted with the horizontal tails located −0.10, 0, 0.10, and 0.20 wing semispans above the chord plane of the wing at longitudinal distances of 1.2 and 1.5 mean aerodynamic chord lengths behind the moment center. The wind-tunnel tests were conducted at a Reynolds number of 2.5 million at Mach numbers from 0.25 to 0.95.

It was found that the horizontal tail was destabilizing at moderate lift coefficients when located above the plane of the wing. When placed either in or below the plane of the wing, the horizontal tail was stabilizing throughout the lift range. For the balanced condition, the drag increment due to the tail was less when the tail was placed 0.10 wing semispan below the wing chord plane than when placed in the wing chord plane. In general, the drag due to balancing the model decreased with increases in tail size or length and increased markedly as the Mach number was increased beyond 0.90.

From authors' summary

2194. Savage, H. F., and Tinling, B. E., The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. II-Lateral and directional characteristics, *NACA TN* 4042, 13 pp. + 71 figs., Aug. 1957.

The effects of vertical-tail size and length on the lateral and directional stability characteristics of both mid- and high-wing airplane arrangements are evaluated. Also evaluated were the directional-control effectiveness of a rudder, and the lateral-control effectiveness of ailerons and of differential deflection of the horizontal-tail surfaces. The tests were conducted at a Reynolds number of 2.5 million at Mach numbers from 0.25 to 0.95.

From authors' summary

2195. Tinling, B. E., and Karpen, A. V., The subsonic static aerodynamic characteristics of an airplane model having a triangular wing of aspect ratio 3. III-Effects of trailing-edge flaps, *NACA TN* 4043, 10 pp. + 30 figs., July 1957.

Wind-tunnel tests were conducted to find the effects of single-slotted flaps on the longitudinal stability at low speed, the rolling effectiveness of trailing-edge ailerons and of differential deflection of the horizontal tail when the flaps were deflected 40°, and the effect of small deflections of the flaps on the lift-drag ratio at Mach numbers up to 0.95.

From authors' summary

2196. Vick, A. R., An investigation of discharge and thrust characteristics of flapped outlets for stream Mach numbers from 0.40 to 1.30, *NACA TN* 4007, 12 pp. + 10 figs., July 1957.

The discharge and force characteristics of a group of flapped auxiliary air outlets, rectangular in cross section, have been investigated over a range of Mach numbers from 0.40 to 1.30. The results of this investigation are presented in a series of design charts. The ratio of outlet total pressure to stream total pressure required to attain a given discharge-flow ratio is shown to decrease markedly with increasing flap deflection and to vary strongly with the Mach number of the external stream. As the flap hinge point moved rearward, discharge-flow ratios were found to increase; flaps of aspect ratio 1 produced better discharge characteristics than those of aspect ratio 2. The force characteristics of these flapped outlets show that at a zero discharge rate the flaps of aspect ratio 2 have much lower drag than those of aspect ratio 1. The flaps of high aspect ratio have shorter chords

with less of the flap exposed to the high-velocity air outside the boundary layer. At low discharge-flow ratios the difference between the measured thrust at any discharge-flow ratio and the measured drag at zero flow is generally much greater than that calculated from the momentum of the discharge air. This difference is obviously a result of the favorable effect of the jet on the drag characteristics of the flaps.

From author's summary

2197. Coles, D., The laminar boundary layer near a sonic throat, Heat Trans. and Fluid Mech. Inst., Calif. Inst. Technol., Pasadena, Calif., June 1957, 119–137.

Author examines compressible laminar boundary layers under the similarity assumptions of Falkner and Skan. Particular attention is given to large values of the Falkner-Skan parameter β—corresponding to flow through a sonic throat preceded by an upstream sink-type flow. When there is no heat transfer at the wall, solutions can be obtained analytically by expanding in powers of $1/\beta$. But with heat transfer, a singular perturbation technique must be employed [see, for example, Kaplan, *ZAMP* 5, 111–135, 1954]. Falkner-Skan profiles are calculated in the zero heat-transfer case. When heat transfer is present the results of Cohen and Reshotko [*NACA TN* 3325] are extended to cover very large values of β.

M. Holt, USA

2198. Alexander, G. L., Development of subsonic and supersonic total temperature probes for a blow-down type wind tunnel, Univ. Texas, Defense Res. Lab. DRL-399, 45 pp., June 1957.

This study is an experimental approach to the development of supersonic and subsonic total temperature probes for a blow-down-type wind tunnel. Probes of small mass and relatively low conductive heat loss were developed for subsonic testing. Heated shields were used to determine the magnitude of radiation errors, and a supersonic, heated shield probe was developed. In both the subsonic and supersonic cases the probes performed with less than 1/2% error. This accuracy could be maintained over wide ranges of temperature variations and transient conditions.

From author's summary

2199. Kell, C., Measurements of the effect of windscreen shapes on the drag of cockpit canopies at transonic and low supersonic speeds using the free-flight model technique, *Aero. Res. Counc. Lond. Rep. Mem.* 3024, 10 pp., 1957.

The effect of changes in the shape of the windscreen on the drag of a cockpit canopy has been measured on models in free flight. Canopies were attached to the models by means of a flexible mounting in such a way as to allow the canopy drag to be measured directly.

The drag of the canopy was measured over a range of Mach numbers between 0.85 and 1.55 and the results show the improvements to be obtained by variations in the sweep of a vee windscreen and changes in the angle of a sloping windscreen.

From author's summary

2200. d'Ewes Thomson, T. A., and Meyer, R. E., On the tilting of nozzle liners, *Aero. Res. Lab. Melbourne, Austral.* A 100, 18 pp. + 7 figs., Jan. 1957.

The effect of a slight tilting on the Mach number distribution in the test-rhombus is determined on the basis of the perturbation theory. Experiments are reported which (1) confirm that the subsonic and transonic perturbations of the flow may be neglected compared with the supersonic perturbations, and (2) indicate that appreciable effects not accounted for by the theory in the present form occur when the flow possesses high local pressure gradients.

From authors' summary

2201. Drummond, W. E., Multiple shock production, *J. appl. Phys.* **28,** 9, 998–1001, Sept. 1957.

A dynamical theory is developed for the explosive production of multiple shocks in metals which undergo a phase transition. In addition to the formation of two compressive shocks, it is found that a rarefaction shock is also produced which will overtake one of the compressive shocks.

From author's summary

2202. Jones, J. J., Experimental investigation of attenuation of strong shock waves in a shock tube with hydrogen and helium as driver gases, *NACA TN* 4072, 12 pp. + 10 figs., July 1957.

An experimental investigation has been made of the attenuation of strong shock waves in air in a shock tube. Time-history measurements were made of the static pressure at several stations in the wall of the tube. The internal diameter of the tube is 3.75 in. Shock-wave-velocity data were taken for a distance along the tube of about 120 ft. The range of the shock-wave Mach number covered was from 5 to 10-1/2 and the initial pressure ahead of the shock wave varied from 5 to 100 mm of mercury. Hydrogen and helium were used as driver gases.

A helium-driven shock wave was found to decay only about one-half as rapidly as a hydrogen-driven shock wave. The pressure level had little effect on the attenuation rate of a shock wave of given strength for the pressure range investigated. The static-pressure measurements indicated that a severe pressure gradient existed in the latter portion of the air flow. This gradient limits the testing time useful for obtaining reliable aerodynamic data.

From author's summary

2203. Bryant, R. A. A., and Grant, J. N. G., Two-dimensional bow shock wave detachment distances *J. roy. aero. Soc. Lond.* **61,** 558, 424–426 (Tech. notes), June 1957.

The purpose of this note is to state, briefly, the results of a shock wave detachment study made by means of the hydraulic analogy.

From authors' summary

2204. Hess, R. V., Interaction of moving shocks and hot layers, *NACA TN* 4002, 65 pp., May 1957.

Interactions are treated of normal and oblique shocks with hot layers at various temperatures. A brief discussion of spherical and cylindrical shocks is also given. Emphasis is on the fact that at very high temperatures the hot-layer shape undergoes drastic changes. The hot layer is forced to accumulate in a growing bubble-shaped region bound to the moving shock. If the cold flow over the bubble is subsonic, it may divide as it approaches the wall at the end of the bubble and cause a cold jet to penetrate under the bubble. A supersonic flow over the bubble can meet the wall with a shock. Under the influence of mixing, the hot-layer flow can no longer accumulate and a separation bubble is formed. It differs significantly from that in steady boundary layers since it is bound to the moving shock.

From author's summary

2205. Ashwood, P. F., and Crosse, G. W., The influence of pressure ratio and divergence angle on the shock position in two-dimensional, over-expanded, convergent-divergent nozzles, *Aero. Res. Counc. Lond. curr. Pap.* 327, 17 pp. + 10 figs., 1957.

Tests have been made to determine the influence of divergence angle and applied pressure ratio on the shock position in over-expanded, Laval-type, convergent-divergent nozzles. The tests covered a range of design pressure ratios between 3.5 and 17.0 and included divergence angles of from 5° to 40°.

An empirical expression has been derived which enables the limiting pressure ratio at which the nozzle just runs full to be calculated, and curves are presented from which the shock position within the nozzle can be obtained.

The variation with design pressure ratio of the maximum pressure ratio obtainable across the exit shock has been determined and the results compared with those predicted using a semi-empirical formula derived from shock-wave boundary-layer interaction experiments. Good agreement has been obtained.

In the absence of a suitable drying plant, humid air had to be used for all the tests. The effects of this on the measured pressure distributions are discussed.

From authors' summary

2206. Belotserkovskii, O. M., Flow past a circular cylinder with a detached shock, *Dokladi Akad. Nauk SSSR (N.S.)* **113,** 3, 509–512, 1957 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., B-131, 7 pp.).

A numerical method of solution is presented for obtaining flow about a circular cylinder in a supersonic stream. Method divides region between body and detached shock wave (whose location is initially unknown) into N strips and obtains an approximate system of $4N$-1 equations, of which $3N$ are ordinary differential equations and N-1 are algebraic equations. This system was solved using an electronic computing machine for a fluid with specific heat ratio of 1.4 and flight Mach numbers $M_\infty = 3.0$ (using $N = 3$) and $M_\infty = 4.0$, 5.0 (using $N = 2$). The numerical results are indicated. A critical review of existing methods (including subject report) for finding supersonic flow about blunt bodies, as well as an extension of one of these methods, was recently presented by Milton D. Van Dyke [Inst. aero. Sci. Preprint no. 801].

H. Mirels, USA

2207. Murray, J. D., Two-dimensional compressible shear flow in a channel, *Quart. appl. Math.* **15,** 3, 231–236, Oct. 1957.

Variation of vorticity due to the divergence of a two-dimensional channel is obtained from considerations of (a) the differential equation for the stream function ψ and (b) Bernoulli's equation for an adiabatic gas flow. Both the completely subsonic and completely supersonic cases are analyzed for a channel divergence area ratio of 2. It is shown that the difference between initial vorticities becomes smaller with increase in velocity in both cases, but, in the subsonic case, the final vorticity is greater than the initial value, the opposite being the case in the supersonic flow. Effect of the divergence of the channel on streamlines is characterized by consideration of the deflection in the initial central streamline. It is found that the deflection in the supersonic case is an order of magnitude smaller and opposite in sign from that found in the subsonic case. Since there is a possibility of "back" flow which could result in breakaway of flow in the subsonic rotational flow through a channel of this type, restrictions on the initial rotation and channel width necessary for no "back" flow are derived.

Author indicates that the case of a divergent channel with general area ratio can be derived using the method of this paper, with a proportionate increase in algebraic labor.

G. J. Nothwang, USA

2208. Ehlers, F. E., A simple graphical method for constructing two-dimensional supersonic flows by means of a drafting machine, *J. aero. Sci.* **25,** 1, 69–70 (Readers' Forum), Jan. 1958.

A simplication of the Puckett field method of characteristics for supersonic two-dimensional flows is explained. By means of special tables given, an engineer can construct the Mach net rapidly, using a drafting machine without any intermediate calculations.

From author's summary

2209. Ferri, A., Clarke, J. H., and Ting, L., Favorable interference in lifting systems in supersonic flow, *J. aero. Sci.* **24,** 11, 791–804, Nov. 1957.

Authors present results of a number of recent studies at Polytechnic Institute of Brooklyn referring to detailed analyses given in reports of the Aerodynamics Laboratory of the Institute. Method of calculating interference depends on estimate of integrated effects of elementary sources disposed to simulate various arrays and combinations of wings and bodies without computing the induced flow field.

By this means, favorable interferences between spaced bodies and wings can be extended beyond the cases of symmetric slender bodies and wings at zero lift to bodies and lifting wings of finite thickness. Examples worked out include a vertical pylon positioned below a flat plate wing and a combination of a lifting wing with an antisymmetrically contoured body. In both cases, favorable interference between the bodies and wings is calculated to produce a reduction in drag associated with a given lift below that due to the bodies and wings separately.

M. A. Mayers, USA

2210. Meyer, R. C., Flow-turning losses associated with zero-drag external-compression supersonic inlets, *NACA TN* 4096, 18 pp., Oct. 1957.

Application of continuity and momentum equation to the internal flow of supersonic zero-external-wave-drag inlets of simple geometry yields a quantitative estimation of the losses arising in the process of turning the flow back to axial direction after compression on centerbody. As author remarks, since downstream flow conditions are assumed uniform, the mechanism giving rise to the so-called turning losses actually is a combination of internal shock and mixing losses. It is found that such losses may become 20% of the computed inlet total-pressure recovery at Mach 4. Minimizing these losses by rounding the centerbody shoulder is also considered. Finally, some consideration is given to similar losses caused by wind-tunnel models, leading to a tunnel starting criterion that supplements the usual contraction starting condition.

Paper is a valuable addition to the study of compressible flow losses in supersonic inlets and wind tunnels.

P. Schwaar, France

2211. Katzen, E. D., Kuehn, D. M., and Hill, W. A., Jr., Investigation of the effects of profile shape on the aerodynamic and structural characteristics of thin, two-dimensional airfoils at supersonic speeds, *NACA TN* 4039, 59 pp., Sept. 1957.

In order to determine the effects of thickness, trailing-edge bluntness, boattailing, and forward profile on the aerodynamic characteristics of thin airfoils, and to provide a check on the available theoretical methods, 31 airfoils were tested. The airfoils were 2, 4, and 6% thick and were tested at Mach numbers of 1.45 and 1.98 at Reynolds numbers of 1.0, 2.0, and 3.5 million in a clean condition and at a Reynolds number of 3.5 million with transition fixed.

The aerodynamic advantage of very thin airfoils was shown by a rapid increase of maximum lift-drag ratio (e.g., from 5.8 to 14.4 at M = 1.45 and a Reynolds number of 1.0 million) as the airfoil thickness ratio was decreased from 6 to 2%. Increased trailing-edge bluntness of the 6-percent-thick airfoils caused a small decrease in maximum lift-drag ratio but a large increase in section modulus; for the 2-percent-thick airfoils, increased bluntness caused a large decrease in maximum lift-drag ratio with only a small increase in section modulus. This has special significance for propeller designers in that it indicates that propellers whose blade elements operate at supersonic speeds should have blunt trailing edges for the thick sections near the hub and relatively sharp trailing edges for the thin sections near the tip. The importance of maintaining a laminar boundary layer on very thin airfoils was shown by the decrease of maximum lift-drag ratio from 14.4 to 11.9, caused by fixing transition at the leading edge of a sharp-trailing-edge 2-percent-thick airfoil at a Mach number of 1.45. The effects of the different forward profiles and changes in boattailing were generally such that a reduction in profile area reduced the minimum drag coefficient. The center of pressure of the

airfoils moved forward with increased thickness ratio and moved aft with increased trailing-edge bluntness. Available theoretical methods were adequate for calculating the lift and pitching moment of the airfoils under all conditions of the tests. The theoretical methods for calculating foredrag and correlation curves for estimating base pressure were adequate for predicting the total drag when the transition position was known.

From authors' summary

2212. Lampert, S., Normal-force characteristics of delta wings at supersonic speeds, *J. aero. Sci.* **24,** 9, 667–674, 682, Sept. 1957.

Some of the more important results of a series of wind-tunnel investigations conducted at the Jet Propulsion Laboratory to determine the aerodynamic force characteristics of delta wings are presented. A family of five delta wings was designed to cover the range of slope ratios, leading-edge slope to Mach wave slope, from 0.15 to 4.1. Lift or normal force characteristics for these wings were systematically studied as a function of Reynolds number and Mach number. The results of these investigations are presented as normal-force coefficients per radian for the Mach number range 1.33 to 4.55. These measurements are compared with the linear theory both as a function of Mach number and slope ratio. It was found that the experimental measurements were in good agreement with, and exhibited the trend of the theory in, the range of slope ratios 0.15 to 0.70; whereas notable departures from the theory were observed for slope ratios greater than 0.70. For a given wing the systematic variation of the wing profile indicated that there existed a much greater dependence of the lift on profile or edge configuration and on Reynolds number for slope ratios greater than 0.70.

From author's summary

2213. May, A., Supersonic drag of spheres at low Reynolds numbers in free flight, *J. appl. Phys.* **28,** 8, 910–912, Aug. 1957.

Values of the drag coefficient have been obtained for spheres in the region $1.5 < M < 3.0$, $350 < Re < 3000$ in the Pressurized Ballistics Range at the Naval Ordnance Laboratory. This region borders, on the low Reynolds number side, one investigated previously. The low Reynolds numbers were obtained by using air pressures of about 7-mm Hg and spheres as small as $\frac{1}{32}$ in. in diameter. A contour map of C_D on Mach number and Reynolds number coordinates has been derived from the experimental data.

From author's summary

2214. Kuhns, P. W., Effects of thermal relaxation and specific-heat changes on measurements with a pneumatic-probe pyrometer, *NACA TN* 4026, 67 pp., July 1957.

Equations evaluating effects of thermal vibrational relaxations and specific-heat changes on measurements in flows with pressures greater than 3×10^{-3} atm, Mach numbers less than 2, and temperatures less than 3000 K are developed theoretically. Simplified working equations, with accuracies adequate for most engineering applications, are given. Three examples illustrate effects of thermal relaxations and specific-heat changes on temperature measurements, and effects of thermal relaxations on critical velocities in nozzle flows. Since available experimental results are for probes having geometries and heat-transfer conditions differing from those geometries and heat-transfer conditions considered in the theoretical analysis, conclusive comparisons of theoretical and experimental results are not made.

E. L. Knuth, USA

2215. Silsby, N. S., External interference effects of flow through static-pressure orifices of an NACA airspeed head at a Mach number of 3, *NACA TN* 4122, 8 pp. + 3 figs., Oct. 1957.

Wind-tunnel tests have been made to determine the static-pressure error resulting from external interference effects of flow through the static-pressure orifices of an NACA airspeed head at a Mach number of 3 at 0° angle of attack. Results were obtained for flow both into and out of the orifices for a range of mass flow from 0 to about 4.2×10^{-4} slugs per second.

From author's summary

2216. Campbell, G. S., Induced rolling moments at supersonic speeds *J. aero. Sci.* **24,** 6, 463–464 (Readers' Forum), June 1957.

Recent supersonic wind-tunnel tests of a missile have shown peculiar rolling-moment effects which were not expected on the basis of the usual slender-body theories. One of the problems encountered on a cruciform missile configuration is described. It is desired to maneuver the missile in the vertical plane, but a disturbance of some kind results in deflection of the vertical control by an amount δ. Although linearized theory would not predict a rolling moment for this condition, the wind-tunnel results exhibited a strong induced rolling moment.

The purpose of this note is to provide a quantitative explanation of this rolling moment and to compare the calculated results with available measurements.

From author's summary

2217. Korst, H. H., and Tripp, W., The pressure on a blunt trailing edge separating two supersonic two-dimensional air streams of different Mach number and stagnation pressure but identical stagnation temperature, Proc. Fifth Midwestern Conf. Fluid Mech., Univ. of Mich., Apr. 1957, 187–199.

Analytical and experimental investigation of the base pressure behind blunt trailing edge two-dimensional bodies with thin boundary layers. Analytical approach follows author's previous work with isoenergetic and compressible mixing concepts. Problem under consideration is of so-called "open wake" type where the conservation of mass in the separated regions is maintained, under steady-flow conditions, by a balance of the mass rates supplied to the wake by one stream and extracted by the other. It is by a rather tedious trial and error calculation of this mass flow balance together with the standard Prandtl-Meyer and shock relations that the base pressure is theoretically obtained. Results of the theory agree well with the conventional and simplified approach involving the peak pressure ratio required to recompress separated turbulent boundary layers. Correlation of the theory with experimental tests showed excellent agreement in 50% of the cases. Author attributed the consistent discrepancies in the other cases to unwanted pressure gradients existing in the experimental air streams.

R. E. Bower, USA

2218. Zartarian, G., and Ashley, H., Forces and moments on oscillating slender wing-body combinations at supersonic speed. I. Basic theory, Mass. Inst. Technol. Fluid Dynamics Res. no. 961, 69 pp., Apr. 1957.

Linearized theory is used, the desired solution being built up by doublet distributions in the wing plane (thus the present analysis does not apply to cruciform missiles). The solution is then obtained by applying a Fourier transformation in the free-stream direction and expanding the resultant integral as a power series (as done by Landahl, Swedish *KTH Aero TN* 40), only the first few terms being retained.

This is applied to calculate the stability derivatives for slow oscillations in pitch and vertical translation of a plane wing of zero thickness mounted symmetrically on a body of revolution. The present theory only applies if no part of the body is aft of the straight trailing edge of the wing. A significant difference from the sonic flight case examined by Landahl is that reduced frequency k does not appear explicitly in any of the derivatives (terms in k^2 being neglected). Thus the results are not limited to simple harmonic oscillations but can be applied to any slowly time-dependent motions.

Graphs of longitudinal stability derivatives are given for a series of delta-wing-body combinations with various fineness

ratios, and the values obtained are compared with slender-body theory and with "exact" linearized theory. Slender-body theory appears wholly inadequate for predicting both the magnitude of the derivatives and for estimating the effect of changes in wing aspect ratio and body diameter.

J. W. Clark, USA

2219. Lew, H. G., and Fanucci, J. B., Effect of yaw on boundary layers at high speeds, Pennsylvania State Univ. TR 9, vi + 40 pp. + 12 figs., Nov. 1956.

The flow over yawed infinite wings in a compressible fluid with heat tiansfer is considered. The similarity solution is discussed for a generalized Falkner-Skan type of external flow, after making the usual assumptions followed by the Stewartson transformation. The calculation was carried out for the first-order terms of a double expansion in terms of a sweep-back parameter and a heat-transfer parameter, but covering a range of the Falkner-Skan-type parameter.

S. F. Shen, USA

2220. Grigorian, S. S., On a problem of finite span wing theory, *Dokladi Akad. Nauk SSSR (N.S.)* **110,** 3, 348-350, 1956.

Author considers the linearized problem of the steady supersonic flow of an ideal gas about a three-dimensional lifting surface with both leading edges subsonic and meeting at a point. He remarks that this problem has apparently been solved only for (1) the conical flow case and (2) special angle-of-attack distributions. The problem is reduced to the solution of a Volterra integral equation of the second kind, and the existence of a unique solution which can be constructed by an iteration process is demonstrated. The solution of a somewhat special case of this problem is sketched by M. A. Heaslet and H. Lomax in "High speed aerodynamics and propulsion", vol. VI, 1954, pp. 214-216.

W. H. Pell, USA

2221. Linnell, R. D., Hypersonic flow around a sphere, *J. aero. Sci.* **25,** 1, 65-66 (Readers' Forum), Jan. 1958.

This note presents an estimate of the stagnation-point surface-velocity gradient and the axial shock-detachment distance for hypersonic flow around a sphere. Real gas effects are taken into account. The predicted values correlate well with available experimental data which are for perfect gas conditions.

From author's summary

2222. Maslen, S. H., and Moeckel, W. E., Inviscid hypersonic flow past blunt bodies, *J. aero. Sci.* **24,** 9, 683-693, Sept. 1957.

Two methods are used for the calculation of the flow field between a blunt body and its shock wave in hypersonic flow. The first is a stream tube method based on an iterative description of the shock wave, assuming the shock "stand-off distance" is known and the surface pressure distribution is given by the Newtonian approximation. The second involves an integral method in which "boundary-layer" coordinates are used and the equations are approximated to some order of k, where k is the ratio of the upstream density to the stagnation point density downstream of a normal shock. A polynomial form for u is taken where the coefficients are determined from the surface velocity and an assumed shock "stand-off" distance. Examples are given in which equilibrium real gas effects are included.

G. M. Lilley, England

2223. Hodges, A. J., The drag coefficient of very high velocity spheres, *J. aero. Sci.* **24,** 10, 755-758, Oct. 1957.

Measurements of velocities of two sizes of spheres have been used to calculate the drag coefficient in the range Mach 2.2 to Mach 9.7. Firings were made from a light-gas gun into open air. It is found that, at Mach numbers from 4 to 10, the drag coefficient is nearly constant and equal to 0.359.

From author's summary

2224. Hertzberg, A., The shock tunnel and its applications to hypersonic flight, *Cornell aero. Lab. Rep.* AD-1052-A-5, 28 pp. + 16 figs., June 1957.

Paper discusses the application of the shock tube to the study of the problems of hypersonic flight. The development of the shock tube into a short-duration wind tunnel for the study of supersonic air flow is reviewed historically. Modifications of the conventional shock tube which extend the shock tube into a tool for the study of hypersonic flows are described. The problems of operation and technique which these modified shock tubes introduce are discussed. The techniques of instrumentation for the brief flow durations of hypersonic shock tunnels are outlined. In particular, a technique is described for accurately measuring heat transfer within the short testing times available in shock tunnels.

Results of preliminary experiments carried out to explore the effects of shock attenuation on the operation of shock tunnels are presented. Since the attenuation becomes so severe at high shock Mach numbers, shock tubes of more sophisticated design are being studied which promise to increase the testing time per unit length of shock tube up to twenty-five times that of the existing shock tubes, and hence alleviate the attenuation problem. A new technique for generating strong shock waves required for shock-tunnel operation is described.

Finally, the present experimental program under way at Cornell Aeronautical Laboratory is briefly reviewed, and the results of some recent interesting experiments are introduced.

From author's summary

2225. Bleviss, Z. O., and Inger, G. R., The normal shock wave at hypersonic speeds, *Douglas Aircr. Co. Rep.* SM-22624, 21 pp., Nov. 1956.

The classical normal shock theory assumes that the specific heats of the gas remain constant throughout the flow field (i.e., C_p, C_v, and, thus $\gamma = C_p/C_v$ are constant). For the diatomic gases of usual interest in aerodynamics, such as air, oxygen, and nitrogen, this assumption is valid only at relatively low supersonic Mach numbers—roughly speaking, for Mach numbers less than about 4 or 5. This assumption breaks down because the temperature behind the shock increases with increasing Mach number and eventually becomes great enough to excite (through the molecular collisions) molecular vibrations; at still higher temperatures, dissociation, ionization, etc., can occur. These "heat sinks" increase the specific heats of the gas and can produce markedly different conditions through and behind the shock wave than those predicted by classical theory.

Exact calculations of the equilibrium states of air behind a normal shock are available in the literature. These presentations are formal and the basic physics remains obscure for those readers not already familiar with the problem.

The purpose of this report is to explain the basic physics in simple terms.

From authors' summary

2226. Yasuhara, M., An exact approach to the hypersonic viscous flow past a slender body of revolution, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 291-294.

A similar solution for the hypersonic viscous flow past a slender body of revolution with radial coordinate proportional to the 3/4th power of the axial distance is obtained. The region of strong interaction between the boundary layer and shock wave is considered and the radius is comparable to the boundary-layer thickness. This solution was obtained previously by the Kármán-Pohlhausen method [Yasuhara, *J. phys. Soc. Japan* **11,** 8,878-886, Aug. 1956; AMR **10** (1957), Rev. 799] and is considered herein by numerical integration. Tendencies of both results are about the same.

H. G. Lew, USA

2227. Wood, W. W., The asymptotic expansions at large Reynolds numbers for steady motion between non-coaxial rotating cylinders, *J. Fluid Mech.* **3,** 2, 159–175, Nov. 1957.

The equations for viscous motion of a fluid contained between two rotating circular cylinders with offset axes are linearized by expanding the stream function. The asymptolic behavior of the solutions for small viscosity is examined but consideration is extended to the first-order stream function only. Boundary-layer methods are used in calculating the leading terms of the expanded stream function. J. F. Lee, USA

2228. Craggs, J. W., The supersonic motion of an aerofoil through a temperature front, *J. Fluid Mech.* **3,** 2, 176–184, Nov. 1957.

Solutions for the equations for sound wave propagation when an infinite wedge passes through a plane interface between different media at supersonic velocity are given. The solutions are worked out for the particular case when two media consist of the same perfect gas at different temperatures. It is then shown that the flow can be deduced by superposition for any symmetrical airfoil of infinite span. The case of the double wedge is considered in detail. J. F. Lee, USA

2229. Dillaway, R. B., A philosophy for improved rocket nozzle design, *Jet Propulsion* **27,** 10, 1088–1093, Oct. 1957.

The conventional conical nozzles for rocket engines (with 15 deg optimum divergence angle, as resulted from German investigations) become unwieldy in both length and exit diameter when extended to higher exhaust area ratios, most effective in increasing engine performance at high altitudes. Paper presents an approach for designing short axially symmetric supersonic nozzles having axially directed exhaust.

The ideal nozzle design should present a unique contour turning the flow of given Mach number without introducing compressive disturbance. Numerical analysis has then been attempted by author, using the characteristic method for isentropic flow with specific heats ratio equal to 1.23. A conventional 1.15 initial value Mach line has been assumed as a compromise between results of calculations after Oswatitsch, Hooker and Sauer methods for the preceding transonic field. The procedure for applying the characteristic method is then presented, resulting in a proper nozzle contour design for various nozzle lengths and area ratios. For very short nozzles where the validity of the isentropic relations is questionable, the oblique shock theory is also used and results compared with those of the characteristic method.

The minimum expansion angle producing the desired increase in momentum within the nozzle has to be chosen to give the most nearly ideal flow; the maximum useful angles resulting in minimum nozzle lengths should obviously be submitted to experimental tests as they involve flow separation tendency and shock losses associated with excessive expansion and recompression.

A. Ghetti, Italy

2230. Jorgensen, L. H., Elliptic cones alone and with wings at supersonic speeds, *NACA TN* 4045, 55 pp., Oct. 1957.

Experimental measurements at Mach numbers of 2 and 3 are compared with theoretical predictions for elliptic cones of cross-sectional axis ratios from 1 to 6 without and with triangular wings of aspect ratios 1 and 1.5. For cones alone, pressure distribution at zero incidence can be predicted by Van Dyke's second-order slender-body theory. Pressure drag decreases with an increase in cross-sectional axis ratio, but the corresponding increase in wetted area adds skin friction which makes total foredrag nearly constant. Linearized wing theory is successful in predicting lift. From these results, neat correlations of lift, pitching moment, and lift-drag ratio are developed from which the properties of elliptic cones can be determined from those of equivalent circular cones. The large lift-drag ratios of elliptic cones with major axis horizontal are clearly demonstrated. For winged cones, an elliptical cross section with the major axis in the plane of the wing increases lift-drag ratio above that of an equivalent circular cross section because of less zero-lift drag and less drag due to lift. The latter result is due to better streamlining in crossflow plane. Forces and moments on wing-body combinations with circular cones can be computed at angles of attack less than 10° by modified slender-body theory but cannot be successfully predicted for elliptic bodies.

An interesting and well-written paper.

W. F. Davis, USA

2231. Kanwal, R. P., Variation of flow quantities along streamlines and their principal normals and binormals in three-dimensional gas flows, *J. Math. Mech.* **6,** 5, 621–628, Sept. 1957.

Three-dimensional steady rotational gas flow without viscosity and heat conduction is discussed from the point of view of differential geometry. Expressions are given for the tangent, principal normal and binormal vectors λ, η, ν of the streamlines and also for the curvature and torsion of the streamlines and of two congruences of orthogonal trajectories. The curves of the one of these families have η as the tangent vector, λ as the principal normal vector, and ν as the binormal vector, while the curves of the other family have ν as the tangent vector, λ as the principal normal vector, and η as the binormal vector. The variations of pressure in the directions of λ, η, ν are investigated. The pressure remains constant in the direction ν. Furthermore, relations connecting the vorticity components with the gradient of entropy and with the curvature of the streamlines and the velocity components in the directions λ, η, ν are established. In the case of plane and axially symmetric flows one obtains well-known results of L. Crocco, A. Vazsonyi and T. Y. Thomas.

R. Sauer, Germany

2232. Ness, N., On the exact solution of compressible Couette flow with mass addition and binary diffusion, *J. aero. Sci.* **24,** 8, 626–627, Aug. 1957.

An exact, closed-form solution of the system of equations describing compressible Couette flow with mass injection and binary diffusion is obtained. Velocity, enthalpy, and diffusion profiles are expressed in terms of simple integrals for the completely general variation of all fluid properties.

From author's summary

2233. Broadwell, J. E., A simple model of the nonequilibrium dissociation of a gas in Couette and boundary layer flow, Douglas Aircr. Co. Rep. SM-22888, 50 pp. + 10 figs., Aug. 1957.

Approximate solutions are found for the temperature and atom concentration profiles in nonequilibrium, dissociating gas flow. A Taylor's series expansion to terms of first order is used for the rate of atom production per unit volume, and the solutions are given in terms of dimensionless parameters. The chemical reaction rate is accounted for by a single parameter. When this parameter becomes large, the gas approaches chemical equilibrium; at the other extremes, no reaction occurs. Only the functional form of the solutions are given, since the values of the coefficients needed to reduce the parameters to quantitative results are as yet uncertain.

The following cases are treated: gas at rest between two plane parallel walls at different temperatures; gas flow between these walls in relative motion (Couette flow); and boundary-layer flow along an infinite flat plate. Both catalytic and noncatalytic walls are considered. A mechanical analogy to the stationary gas and Couette flow problems is developed. This provides a convenient means of visualizing the influence of the dimensionless parameters and of the boundary conditions on the temperature and concentration profiles. A. J. Eggers, Jr., USA

2234. Drake, D. G., The oscillating two-dimensional aerofoil between porous walls, *Aero. Quart.* **8,** 3, 226–239, Aug. 1957.

The compressible flow past an oscillating two-dimensional airfoil in a wind tunnel with porous walls is considered, using linearized theory. The porous wall is assumed to have the property that the ratio of the normal velocity at the wall to the pressure drop across the wall is constant. Transform theory is used to find the supersonic longitudinal stability derivatives, and an extension of Possio's integral equation for the quasi-stationary case in subsonic flow.

From author's summary by W. P. Jones, England

2235. Dini, D., Applications of the theory of one-dimensional flow to the study of unsteady fluid flow in rotating pulse-jets (in Italian), *Aerotecnica* **37,** 3, 107–128, June 1957.

With reference to an application of rotating pulse-jet with a load composed in part of mixture at stoichiommetric ratio, and in part of air, the pattern of pressure and velocity waves is studied for the flow in a horizontal tube rotating around one of its ends. Assumption is made, in a first analysis, that the fluid is homogeneous and at constant entropy, and then the influence is appraised of the different levels of entropy between the fluid in which combustion is developing and that participating essentially in the propulsion. In the second analysis, consideration is given to the behavior of combustion, and useful elements related to the possibility of operation of a rotating pulse-jet and cycle durations are derived in fair agreement with measured frequencies of normal pulse-jets.

From author's summary by A. Balloffet, USA

2236. Kekhain, A., and Lis, L., One-dimensional interrupted flow with heat supply or entropy gradient (in Russian), *Vopros. goreniya. Sb. perev. in. period. lit.* **1,** 231–243, 1953; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6489.

Differential equations for propagation of one-dimensional waves in a flow are derived for cases when heat sources or an entropy gradient are present. Their use for the calculation and analysis of a flow in pulse and ramjet engines is shown.

The graphical solution of the equations is explained by the characteristics method. M. A. Peshkin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2237. Crane, L. J., The laminar and turbulent mixing of jets of compressible fluid. Pt. II. The mixing of two semi-infinite streams, *J. Fluid Mech.* **3,** 1, 81–92, Oct. 1957.

Methods developed by Crane and Pack in an earlier paper (AMR **11,** Rev. 1282) are applied to the mixing of two parallel streams. With laminar flow the mixing region is narrower the higher the Mach number. With turbulent flow, the influence of compressibility on the form of the nondimensional velocity profile is almost negligible. This is confirmed by measurements of Laurence [*NACA TN* 3561] for a jet at Mach number 0.7 entering a medium at rest. The effect of temperature differences is shown to be rather unimportant even if these are considerable.

H. Schuh, Sweden

Wave Motion in Fluids

(See also Rev. 1999)

2238. Paynter, H. M., and Ezekiel, F. D., Water hammer in nonuniform pipes as an example of wave propagation in gradually varying media, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-107, 8 pp.

Wave disturbances propagate down a fluid pipe, whose characteristics vary only gradually over a single wave length, in nearly the same manner as a uniform pipe of the same total transmission time. However, the variations in pressure and flow along the pipe are modified directly and inversely, respectively, with the square root of the change in characteristic impedance level. This generally useful "Green's Law" approximation is checked against exact solutions and other methods of approximation. Author stresses the analogous nature of water hammer with other types of wave propagation in varying and stratified media, as transients in tapered electric transmission lines, seismic waves in the ground, vibrations in turbine shafts, tidal waves in river estuaries, and acoustic propagation in horns.

An instructive table of the analogous quantities in various wave media is given. Numerical examples are worked out. Appendices give derivation of the canonical and of the characteristic equations used. K. J. De Juhasz, Germany

2239. Edge, P. M., Jr., Impact-loads investigation of chine-immersed model having a circular-arc transverse shape, *NACA TN* 4103, 9 pp. + 1 table + 12 figs., Sept. 1957.

An investigation of hydrodynamic impact loads on chine-immersed bodies of heavy beam loading at the Langley impact basin has been expanded to include transversely curved models in addition to models of prismatic shape. This paper presents the results from tests of a chine-immersed model having a circular-arc cross section with a radius of 1 beam. The results were obtained from fixed-trim impacts made in smooth water over a wide range of trim and initial flight-path angles. Most of the impacts were made at a beam-loading coefficient of 16.59, with a few impacts at beam-loading coefficients of 27.59 and 36.57.

The data are presented in tables, and the coefficients of loads and motion are presented in figures as a function of trim and initial flight-path angles. The circular-arc model experienced loads greater than loads predicted by theory for this configuration by about 10%. These loads are as much as 12% less than the loads measured under similar conditions for a model with concave-convex cross section with a similar effective angle of dead rise.

From author's summary

2240. Edge, P. M., Jr., and Mixson, J. S., Impact-loads investigation of a chine-immersed model having a longitudinally curved bow and a V-bottom with a dead-rise angle of 30°, *NACA TN* 4106, 10 pp. + 2 tables + 12 figs., Sept. 1957.

As part of a program to study the effects of transverse and longitudinal curvature on impact loads of chine-immersed models, a V-bottom model having a dead-rise angle of 30° and the forward half longitudinally curved upward on a radius of 10 beams has been tested at the Langley impact basin. Impacts were made in smooth water at a beam-loading coefficient of 18.8 with the trim angle held fixed throughout each impact. Impacts with forward speed were made over a range of trim angles from −3° to 30° and initial flight-path angles from 3.5° to 27°, and a few impacts without forward speed were made at a trim angle of 0° for several vertical velocities.

The data are presented and analyzed to determine the extent of bow immersion during the impacts. The curved bow was found to be not immersed at the high trim angles (15° and 30°), only slightly immersed at trim angles of 6° and 9°, and almost totally immersed at trim angles of 3° and below. The impact loads and motions obtained are presented in coefficient form as variations with trim and initial flight-path angles. The maximum impact loads are shown to be in substantial agreement with loads predicted by theory for the non-bow-immersed case; however, comparisons at 3° trim, where the bow is immersed, show maximum loads that are less than the loads predicted by theory for a straight-keel model.

From authors' summary

2241. Binnie, A. M., Experiments on the onset of wave formation on a film of water flowing down a vertical plane, *J. Fluid Mech.* **2,** 6, 551–553, Aug. 1957.

The supply of water to the outside of a long vertical tube was adjusted until the water film was seen to be only just disturbed by a train of traveling waves. Under these conditions the Reynolds number, defined as the discharge per unit width divided by the kinematic viscosity, was 4.4. The wave train was slightly irregular, and average values of the length and velocity of the waves were about 0.45 in. and 5½ in./sec., the temperature being 19C.

From author's summary

2242. Chappelear, J. E., The calculation of wave forces on a sunken obstruction, *J. Petr. Technol.* **9,** 8 pp., Aug. 1957.

Author resolves the two-dimensional problem for a rectangular body (e.g. drilling barge) submerged in ocean of constant depth, waves coming toward the long side of obstacle. Linearized (Airy's) theory of waves is assumed, consequently only the first term of Fourier's development is considered. Author indicates also a simplified manner to take account of the further terms (Stokes-Struik's theory) but does not effect it.

In the region nearest to obstacle (about half wave-length to each side), author calculates the velocity-potential ϕ by numerical methods; farther away he supposes for it the common sinusoidal distribution for incident, reflected, and transmitted waves. In the frontiers of these regions, ϕ is supposed to be continuous, but $\partial\phi/\partial\kappa$ can't be, and its discontinuity denotes the degree of approximation reached. Author simplifies resolution by decomposing running waves into symmetrical and antisymmetrical standing wave systems, and so separates the time functions. Complete calculations for two cases are performed: for wave periods of 6 sec and 10 sec, both for a barge of 80 ft wide × 16 ft high × infinite length, ocean depth 40 ft.

Concerning the calculation procedure author says the finite differences method was employed for adjusting the solutions of the Laplace equation to the boundary conditions. The relaxation method was rejected as impractical in this case, being used only to check final results. Velocity potential ϕ was decomposed into seven partial functions, and for each of them about 60 simultaneous equations were solved, then 7 equations more to adjust the whole. Calculations were long and tedious: about two weeks' work on desk calculator and some more operations on electronic digital computor (with 16 significant figures). Author suggests, and reviewer agrees with him, calculus like this, being extensive, must be used only to elaborate or to check other more abbreviated methods, but never as routine procedure.

Then author calculates the total force acting on the submerged body, and compares it with an estimation by the "usual engineering approximation" corrected with a "dynamical coefficient" (≈ 1.5); a sufficient coincidence was obtained. Some data about wave profile in proximity of body, phase shift and reflection coefficient are given, too.

N. Krivoshein, Argentina

2243. Lunchick, M. E., Eibling, J. H., and Short, R. D., Jr., A feasibility study of methods for simulating by static forces the nonuniform hydrodynamic pressures on sonar domes, *David W. Taylor Mod. Basin Rep.* 1134, 21 pp., May 1957.

The use of rubber pressure cells to simulate hydrodynamic loads statically is discussed. Tests on a flat plate to ascertain the validity of the method are described. Although the method is feasible for testing flat plates, it is anticipated that a complex shape like a sonar dome would involve a much more extensive test procedure.

From authors' summary

2244. Breslin, J. P., Application of ship-wave theory to the hydrofoil of finite span, *J. Ship Res.* **1,** 1, 27–35, 55, Apr. 1957.

The theory of ship-wave drag appears to receive some benefit from aerodynamics. A hydrofoil is an aquatic wing. Application is made to a straight wing hydrofoil moving beneath a free surface. Hydrofoil craft, or "flying hulls," have been built with wings attached by struts to a boat hull. High-speed drag is reduced, and a smoother ride obtained in rough water.

This paper is based on work originally supported by the Office of Naval Research. In it is shown that a finite-span hydrofoil produces a wave drag that can be found directly from a free surface theory for ship hydrodynamics (two fluids). This theory, for deep water, is given by Havelock and others. Then, at high Froude numbers, the induced drag can be deduced from usual aerodynamic theory (single fluid).

Resulting formulas are evaluated for two arbitrary load distributions, and then compared with model tests. An approximation shows the influence of gravity in the high Froude number range, from which one can deduce a Froude number beyond which gravity effects can be ignored.

In addition, the general ship hydrodynamics formulas lead to an expression for waves considerably aft of the hydrofoil. Wave pattern is discussed, with emphasis on centerline profile for high Froude numbers; and a contrast is noted for two-dimensional theory (cross section and infinite span) for hydrofoil wave resistance.

German developments during World War II stimulated great interest, here, in hydrofoil craft. Certain people believed that very large values of lift-drag ratio might be obtained by using two foils, the second in the wake of the first, recovering all the wave drag of the first. Experimental studies supported by the U. S. Navy have discounted completely the practicability of achieving lift-drag ratios in excess of those for aircraft.

The results in this paper corroborate answers from a solution by Y. T. Wu, of May 1953. Similar results can be obtained easily for other configurations without use of complete theory. Finite span and infinite span wave drag are contrasted, and comparison made with wave patterns at high Froude numbers. The part of drag at high speed which depends on Froude number is small, but it is important to know at what Froude number this is true; and to know that ship theory can be applied readily to the hydrofoil. Use of Havelock's work depends on determining the undisturbed potential of a wing in a infinite fluid.

For wings of aspect ratio exceeding 4, Prandtl replaced the wing by a vortex distribution: of bound vortices and two trailing vortrices, and using a potential function, containing vortex strength or circulation, and partials and direction cosines, tied to the geometry of the foil.

One formula can be recognized as the potential of a doublet distribution, which is a key to use here of Havelock's work. The general formula for wave drag for any hydrofoil can be given since the wing potential is made up of strips or panels of doublets whose axes are normal to these panels which stretch infinitely astern.

An interesting result, given graphically, for increasing Froude numbers, indicates greatly decreasing transverse-wave drag, but increasing (to a limit) lateral-wave drag. The total drag increases at first, for the two kinds of waves, and then drops off to a minimum limit of somewhat less than half its maximum value. Of three arbitrary distributions of circulation, a cosine distribution gave the highest drag curve, an elliptic gave lower, and a rectangular one gave the lowest drag. Again, a three-dimensional theory, with elliptic distribution, gave a lower drag curve than did a two-dimensional theory tho' the two curves were similar, and not too far apart.

E. Smith, USA

2245. Unoki, S., On the ocean waves due to tropical cyclones (2nd paper); Distribution of waves viewed from geometric consideration and typhoon reconnaissance by aircrafts, *J. meteor. Soc. Japan* **35,** 2, 78–87, Apr. 1957.

Distribution diagrams of swell in a tropical cyclone, constructed under a simple geometric consideration, agreed satisfactorily with

what had been shown by Cline, Tannehill, Ootani, Arakawa and others, and the variety of the distribution according to the speed and track of the storm was discussed quantitatively. Particularly when the speed of the storm exceeds that of swell, it is noticeable that we can find the swell with almost an opposite direction from the wind in the left rear quadrant of the storm and the swell with a direction deviating from the wind to the left, contrary to Tannehill's consideration, in the right rear quadrant.

Based upon a report on the typhoon reconnaissance by aircrafts, the variation of the state of the sea and swell with the development of the storm was investigated. It was also shown that, in the case of typhoon associated with a frontal system, the confused sea or the swell with an unusual direction is likely to be raised in the adjacent seas of the front. The facts that the sea in the eye of the storm is less confused when the storm moves slowly, very confused when it moves with almost the same speed as that of the wave, and somewhat confused when it moves very rapidly were found and were explained theoretically. Moreover, author discusses the fact of there being other regions in the storm than the eye, where the confused sea is raised.

From author's summary

2246. Sretenskii, L. N., Directional propagation of waves from a region undergoing external pressure changes (in Russian), *Prikl. Mat. Mekh.* **20,** 3, 349–361, May–June 1956.

Paper is a thorough analysis of wave action in horizontal directions in an infinitely deep mass of a fluid subjected in a limited part of its surface to pressure changing its intensity with time in accordance with laws of harmonic motion. Theoretical investigations are based on the assumption that the potential of velocity $\varphi(x, y, z, t)$ complies with Laplace equation for both extreme conditions (for surface $z = 0$, and for infinite depth $z = -\infty$). Reference is made to Whittaker, E. T., and Watson, G. N., "A course of modern analysis," par. 94. See also Whittaker, E. T., "A treatise on the analytical dynamics of particles and rigid bodies," Dover Publications, New York, 1944. J. J. Polivka, USA

2247. Sretenskii, L. N., Wave propagation in an elastic semi-space for the motion of a tidal wave on the surface of a circular basin (in Russian), *Trudi. Mor. gidrofiz. in-ta Akad. Nauk SSSR* **6,** 10–23, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7779.

The propagation of elastic waves is examined in a semi-space, $z \geqslant 0$, on the condition that, at the boundary $z = 0$, the tangent stresses become zero, while the normal stress is determined as follows:

$$\tau_{zz} = \begin{cases} f(r)\, e^{i(\sigma t + s\varphi)} & \text{for } r < a \\ 0 & \text{for } r > a \end{cases}$$

The solution of the problem is obtained in Fourier-Bessel integrals. The case is examined in detail of $s = 2$ and $f(r) = k(r/a)^2$, where k is a constant.

In evaluating the integrals for this case, the methods of transits and asymptotic comparisons are used. The displacements are analyzed, both within the semi-space and on the boundary thereof. It is demonstrated that on the boundary of the semi-space, at great distances from the source, the displacements formed additively of the displacements due to the passage of longitudinal and transverse waves, decay rapidly with increasing r (as r^{-2}).

K. I. Ogurtsov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Turbulence, Boundary Layer, etc.

(See also Revs. 1883, 2179, 2197, 2219, 2226, 2323, 2349)

2248. Stewartson, K., On asymptotic expansions in the theory of boundary layers, *J. Math. Phys.* **36,** 3, 173–191, Oct. 1957.

This is a reconsideration of four specific flows admitting "boundary-layer-type" approximation. Attention is focused upon the often-ignored questions of upstream boundary conditions and the attenuation of the viscous disturbance as $y/x^{\frac{1}{2}} \to \infty$. The specific cases are (1) flat plate wake, (2) hypersonic boundary layer, (3) boundary layer along a semi-infinite circular cylinder, and (4) flat plat boundary layer with suction. Definite progress is made although there still appear to be some unanswered questions.

One passing remark is not clear to reviewer: referring to (2), author describes the dividing line between the ("conventional") viscous wall layer and the intermediate inviscid zone as a streamline. Also worth mentioning is the fact that in problem (3) he chooses to make the velocity equal to the undisturbed value everywhere in the plane $x = 0$, the leading edge station.

S. Corrsin, USA

2249. Johnson, C. H. J., Aerofoils in cascade with boundary layer control, *Aero. Res. Lab., Melbourne, Austral.* ME 222, 7 pp. + 2 fig., July 1957.

A design is presented of a cascade of airfoils with boundary-layer control obtained by using distributed suction.

From author's summary

2250. Kramer, M. O., Boundary-layer stabilization by distributed damping (Readers' Forum), *J. aero. Sci.* **24,** 6, 459–460, June 1957.

The transition of the boundary layer from laminar to turbulent is a consequence of a dynamic instability that develops with increasing Reynolds number. Thus it was felt that the introduction of artificial damping might increase the stability of the boundary layer. A systematic series of tests was conducted in order to study this novel approach to an artificial boundary-layer stabilization. From author's summary

2251. Wallis, R. A., and Ruglen, N., Note on the breakdown of the laminar separation bubble on the nose of a thin wing, *Aero. Res. consult. Comm. aero. Res. Lab. Melbourne, Austral. Note* A.161, 14 pp. + 12 figs., May 1957.

Wind-tunnel experiments on a nose flap model support the theory that nose stalling on a thin wing is the direct result of turbulent separation from near the leading edge for moderate to high Reynolds numbers. The influence of the laminar separation bubble on this separation is discussed. From authors' summary

2252. Racicot, E. A., An experimental investigation of laminar boundary layer profiles in a weak adverse pressure gradient at an incident Mach number of three, *Univ. Toronto Inst. Aerophys. Rep.* 46, 15 pp. 1 table + 18 figs., Mar. 1957.

Experimental pitot pressure profiles through a laminar boundary layer in supersonic flow and under a weak adverse pressure gradient are compared with the predictions of the theory of G. M. Low. Some information is presented about the effects of probe geometry on the shape of the measured profile.

From author's summary

2253. Hasimoto, H., Boundary-layer slip solutions for a flat plate, *J. aero. Sci.* **25,** 1, 68–69 (Readers' Forum), Jan. 1958.

2254. Senoo, Y., Three-dimensional laminar boundary layer in curved channels with acceleration, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-173, 24 pp.

A theory is developed for two families of three-dimensional laminar boundary layers; namely, for the boundary layer on the parallel plane end walls of a curved channel with logarithmic spiral side walls, and for the boundary layer on the plane end wall of a concentric circular-arc channel having a particular family of accelerated or decelerated main flows. Numerical calculations show

that acceleration makes the boundary layer thin and deceleration makes it thick, but the variation of thickness due to pressure gradient is very small compared with that in the two-dimensional case. The first case can be compared to the flow in a cascade. Experimental data on the end wall of a turbine-nozzle cascade were compared with the theoretical prediction, with fair agreement across the nozzle and along the center line of the nozzle.

From author's summary by W. R. Hawthorne, England

2255. Eichelbrenner, E. Z., Separation of the three-dimensional laminar flow around a finite body (in French), *ONERA Publ.* 89, 37 pp., 1957.

Writer considers the problem of the separation of the three-dimensional incompressible laminar boundary layer around a finite body. Gruschwitz proposed to use for this purpose the criterion of two-dimensional flow (vanishing partial derivative of the longitudinal velocity component with respect to the normal coordinate at the wall). But more proper is Sears criterion [AMR **1**, Rev. 483 (1948)] modified by Oudart. The writer proposes an intrinsic three-dimensional criterion using geometric considerations and a hypothesis on the regularity of the viscous fluid flow. This is applied to a flow around an ellipsoid of revolution at various angles of incidence. The results are represented by means of extremely interesting and carefully drawn color diagrams.

In part II of the report Mr. Gilon applies the method of Maruhn [*ZWB-Ber.* FB 117411, 1940] to calculate the potential flow on the surface of the ellipsoid. Application of the Eichelbrenner criterion of the separation furnishes the curve along which the separation occurs. The visualization tests in a wind tunnel by means of a chemical reaction seem to confirm the analytical results.

This is a valuable addition to the theory of separation.

M. Z. v. Krzywoblocki, USA

2256. Bertotti, B., Secondary flow in the three-dimensional boundary layer (in Italian), *Atti Accad. naz. Lincei R. C. Sci. Fis. Mat. Nat.* **22**, 4, 455–458, Apr. 1957.

Author studies the possibility of occurence, within the boundary layer, of flow in a direction normal to the exterior stream. Author applies Levi-Civita's method ["Allgemeine Folgerungen aus der Prandtlschen Grenzshichtheorie." Vortrage aus dem Gebiete der Aerodynamik und verwandter Gebiete, Aachen, 1929, p. 30] to prove that such secondary flow is always present unless the projection of the external streamlines on the boundary be geodetic lines of this surface. This is the case for a body of symmetry of revolution.

A. Balloffet, USA

2257. Yamaga, J., An approximate solution of the laminar boundary layer on a rotating body of revolution in uniform compressible flow, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 295–298.

2258. Reshotko, E., and Tucker, M., Approximate calculation of the compressible turbulent boundary layer with heat transfer and arbitrary pressure gradient, *NACA TN* 4154, 34 pp., Dec. 1957.

The method involves the momentum integral and moment-of-momentum equations simplified by Stewartson's transformation, and the Ludwieg-Tillmann skin-friction relation put in a form suitable for compressible flow with heat transfer by means of the reference enthalpy concept. Both two-dimensional and axisymmetric flows are considered. In the case of heat transfer at the wall, use is made of a tentative extension of Reynolds analogy and a number of additional assumptions, all based on analogies with laminar flow. For zero pressure gradient, the present method gives results in good agreement with those obtained by previous methods.

D. W. Dunn, Canada

2259. Covert, E. E., The stability of binary boundary layers, Mass. Inst. Technol., Nav. supersonic Lab. TN 217, v + 28 pp. + 4 figs., June 1957.

The steady properties of a binary boundary layer, i.e., a boundary layer consisting of a mixture of two component gases, have indicated that there are practical advantages in cooling a surface by introducing a foreign gas into the boundary layer. However, since the calculations are based on laminar flow, it was deemed advisable to consider the stability of the binary laminar-boundary layer. The results indicate that, for relatively small injection rates which insure that the boundary-layer approximation is still valid, the stability can be calculated for the binary boundary layer (and, incidentally, an n-component boundary layer) in the usual way, based upon the steady-state velocity and density profiles, without additional complications due to added equations.

From author's summary

2260. Favre, A. J., Gaviglio, J. J., and Dumas, H., Spacetime double correlations and spectra in a turbulent boundary layer, *J. Fluid Mech.* **2**, 4, 313–342, June 1957.

Transition to turbulent flow in the boundary layer of a flat glass plate with zero pressure gradient was produced by increasing the turbulent intensity upstream of the plate or by increasing the surface roughness. Space-time correlations and spectra were measured and presented in a large number of figures. The numerous experimental results should be of interest for further studies. Most of the results were reported earlier in a publication in French [*Recb. aero.* no. 48, 1955].

F. N. Frenkiel, USA

2261. Ruth, R. F., and Yang, H. H., Empirical correlation for velocity distribution of turbulent fluid flow, *AIChE J.* **3**, 1, 117–120, Mar. 1957.

2262. Komoda, H., On the effect of free-stream turbulence on the structure of a turbulent wake (in English), *J. Japan Soc. aero. Engng.* **5**, 45, 274–279, Oct. 1957.

Effect of grid turbulence on the development of a turbulent wake flow produced behind a 1-mm cylinder was investigated with the hot-wire anemometer. Intensity, scale, shear correlation and intermittency factor were all measured. Results seem to indicate that the large eddies are not much effected but the small-scale component of the turbulence is sufficiently increased.

L. S. G. Kovasznay, USA

2263. Elrod, H. G., Jr., Note on the turbulent shear stress near a wall, *J. aero. Sci.* **24**, 6, 468–469, (Readers' Forum), June 1957.

Purpose of this note is to show the manner in which the turbulent contribution to shear stress vanishes in the neighborhood of a wall bounding the two-dimensional, established flow of an incompressible fluid.

From author's summary

2264. Robertson, J. M., The turbulent velocity distribution in rough pipe, Proc. Fifth Midwestern Conf. Fluid Mech., Univ of Mich., Apr. 1957, 67–84.

A well-documented review of data available on pipe flows, including pipes of commercial grades. Emphasis is put on the ratio of maximum velocity to average velocity. The relation between this ratio and the friction factor is still poorly defined. In practical applications, this can introduce significant errors.

The results of Nikuradse are reconsidered and discussed.

R. Betchov, USA

2265. Smith, D. W., Turbulent skin-friction measurements on a smooth flat plate in incompressible flow, Proc. Fifth Midwestern Conf. Fluid Mech., Univ. of Mich., Apr. 1957, 108–121.

Measurements are presented of local surface shear stress, by floating-element balance, and values of average skin-friction coef-

ficient, from boundary-layer profiles, in incompressible flow for a turbulent boundary layer on a smooth plate with zero pressure gradient, in the range of Reynolds numbers from 10^6 to 45.10^6. Scatter in the data is about ± 2%.

Local friction coefficients agree well with those of Schultz-Grunow for all the range of Reynolds numbers, the leading edge being chosen as the origin of the turbulent boundary layer. Average friction coefficients are a maximum 4% below those computed using the Schoenherr formulation. The empirical parameters of the Coles' equations [*Calif. Inst. Technol., Jet Propulsion Lab. Rep.* no. 20-69, 1953] are not constant but the maximum Reynolds number investigated (45.10^6) was not large enough to give a firm indication of the "asymptotic" value of the constants.

E. Brun, France

2266. Laurence, J. C., and Benninghoff, J. M., Turbulence measurements in multiple interfering air jets, *NACA TN* 4029, 37 pp., Dec. 1957.

Turbulent and mean-flow characteristics of several noise-suppression multiple-jet nozzles have been determined from hot-wire-anemometer measurements for flow conditions of Mach number 0.3 and Reynolds number of 2.06×10^6 per foot. Turbulent mixing, as indicated by reduced intensity and scale of the turbulence, occurs closer to the nozzle in interfering than in noninterfering jets. The turbulence spectra show that the multiple jets redistribute energy. The more rapid mixing of the interfering jets and shifting of the spectral energy of the interfering jets may explain, in part, the suppression of noise by these nozzles.

From authors' summary

Aerodynamics of Flight; Wind Forces

(See Revs. 2120, 2138, 2212, 2216, 2218, 2220, 2223, 2234, 2249, 2286, 2287, 2288, 2312, 2373)

Aeroelasticity (Flutter, Divergence, etc.)

(See Revs. 2234, 2370, 2371)

Propellers, Fans, Turbines, Pumps, etc.

(See Revs. 1871, 1872, 1873, 1875, 1958, 1950, 1963, 1993, 2179, 2229, 2280, 2290, 2291, 2327, 2331, 2332, 2335, 2356, 2373, 2374)

Flow and Flight Test Techniques

(See also Revs. 2202, 2214, 2239, 2240, 2303, 2310)

2267. Hassan, K.-E., A new type of hot-element directional anemometer, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-197, 7 pp.

Instrument is a variant of the hot-wire anemometer in which the wire is replaced by a platinum ribbon placed edge-on to the flow to obtain directional sensitivity. Accuracy of up to ± 0.5° in the velocity range of 1 to 3 mps is claimed. Element in present models requires 5-10 amperes heating current, but author believes that much smaller dimensions can be used without loss of accuracy.

D. C. Collis, Australia

2268. Murdock, J. W., and Goldsbury, J., Problems in measuring steam flow at 1250 psia and 950 F with nozzles and orifices, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-88, 9 pp.

2269. Combes, J. J., and de Pasquale, M. J., Flow measuring devices, *Automation* **4,** 9, 47-60, Sept. 1957.

Authors describe the various available devices for flow measurement, their operating principles, advantages, disadvantages, and applications.

From authors' summary

2270. Staab, F., Piezoelectric devices for determining the total static and dynamic pressures and the impulse of a pulsating flow (in German), *Ing.-Arch.* **25,** 404-413, 1957.

Author describes combined sampling tubes and sensing elements capable of rapid response in measuring static and dynamic pressures in streams in nonsteady flow such as the jets of reaction types of propulsion engines. These devices utilize the piezoelectric effect of quartz elements built into the sampling tube and arranged to be stressed by the pressure to be measured. The quartz elements are sealed from direct contact with the gas and may be water-cooled. Rapid response and low attenuation may be expected as a result of the low volume and virtual absence of connections filled with fluid. The electric charge appearing on the quartz surface is amplified electrically.

Various modifications and applications are described, and examples are given of oscillograph traces obtained in tests. Only general dimensions are given but neither calibration nor test data are quoted.

M. A. Mayers, USA

2271. Schroder, R., New aspects of current meter use (in German), Mitt. Inst. Wasserbau no. 45, 37-45, 1956.

A small current meter developed for velocity measurement in hydraulic laboratory. Horizontal axis rotates between conical bearings. Of the four plastic blades, one has metallic insert. Revolutions are transferred by induction to an electronic counter. Blades of 3-cm diameter permit to take points close to walls. This construction is similar to miniature meters by G. B. Pegram (1936), H. R. Dedow and R. F. J. King (1954) in Wallingford Laboratory. Instrument is still to be improved, particularly adapting component runner for a correct projection of velocity.

S. Kolupaila, USA

2272. Wolff, E. R., The development of a mass flow probe, *Univ. Toronto Inst. Aerophys. Rep.* 12, 18 pp. + 5 tables + 29 figs., Jan. 1957.

An investigation was made to determine all of the flow quantities in a supersonic free-stream or boundary layer, using the measured mass flow as one of the independent parameters. Two circular mass flow probes with an entrance opening of 0.064-in. diam and 0.040-in. diam and suitable test equipment have been developed and tested in the Institute of Aerophysics' 5 × 7-in. supersonic wind tunnel. The measurements show that the mass flow probe is a suitable device for determining free-stream supersonic Mach numbers. They were found to be in agreement with those from pitot and static pressure measurements within 2.7%. The mass flow probe, however, fails to operate in and below the transonic Mach number range. Consequently, it cannot be used near the wall of a supersonic boundary layer. But in that portion of the boundary layer where it works without mass flow spillage, it may be readily applied also for the determination of boundary-layer temperature profiles.

From author's summary

2273. Holdaway, H. W., A note on electromagnetic flowmeters of rectangular cross section, *Helv. phys. Acta* **30,** 1, 85-88, 1957.

Paper is intended to supplement that of Thurlemann. It is demonstrated that, for two-dimensional flow distributions in a conduit subject to a uniform transverse magnetic field, the emf generated between two opposite conducting faces of the rectangular cross section is proportional to the true average velocity of flow, irrespective of the nature of the two-dimensional distribution. The form of analysis employed permits an examination also of the ef-

fect of internal resistance of the unit when connected to an external measuring circuit. From author's summary

2274. Kamzoklin, V. V., and Bashkirov, A. N., Apparatus for measuring the velocity of a gas flow at high pressure (in Russian), *Zavod. Lab.* **21**, 6, 743–744, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6796.

After a valve is closed, the gas flow passes into a bypass pipe, having a small resistance, to which two vessels having a sealing liquid are connected in series. The gas discharge is determined from the measured rate of the overflow of liquid.

B. A. Fidman
Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2275. Miller, D. R., and Comings, E. W., Static pressure distribution in the free turbulent jet, *J. Fluid Mech.* **3**, 1, 1–16, Oct. 1957.

Although free jets have been often investigated, more detailed static pressure measurements were lacking. Authors close this gap as far as the incompressible two-dimensional jet is concerned. A disk placed parallel to main flow direction is used as a pressure probe and maximum error of measurements is estimated to be of the order of 5%. The mean static pressure is negative throughout the fully developed turbulent region, and pressure profiles are not of a self-preserving form within range of measurements. A close correspondence between static pressure and turbulent stresses exists. Results confirm earlier assumptions that the static pressure is of minor importance in equation of motion in main flow direction. However in the lateral motion, the static pressure and the lateral turbulent stress are the two dominant stresses, confirming a recent analysis of A. A. Townsend [AMR **9**, (1956), Rev. 4000]. Measurements of mean velocities and longitudinal turbulent stresses are in agreement with past work.

H. Schuh, Sweden

2276. Wehrmann, O., Hot wire measurement in a split-up Karman vortex street, Dtsch. Versuchsanstalt Luftfahrt Rep. 43, 31 pp. + 44 ref., July 1957.

Detailed flow measurements were carried out with an a-c coupled hot-wire anemometer in the flow field of a vortex street in the wake of a circular cylinder. The novel configuration is the use of a splitter plate to isolate the two rows of vortices so that they can be observed relatively independently. Author uses a novel evaluation technique to ascertain the location and velocity distribution of the vortex cores. L. S. G. Kovasznay, USA

2277. Talvitie, N. A., and Paulus, H. J., Recording, photometric particle-size analyzer, *Rev. sci. Instrum.* **27**, 9, 763–767, Sept. 1956.

A recording, photometric particle-size analyzer has been developed for comparing the particle-size distribution of dusts in the subsieve range. The instrument follows the progress of sedimentation of a suspension by means of a collimated beam. Provision for continuously varying the sedimentation depth allows analysis of the entire range within one hour. The optical system and temperature control were designed to increase the accuracy of analysis of the finer particles. A simplified system is given for calibrating the sedimentation curves in terms of particle size. The instrument comprises a small light source and a lens system which directs a pencil of light through two slits between which the sedimentation chamber is located. In the same axis is located the receiving photocell. Whenever particles in the progress of sedimentation pass through the line of the slits, they act as lenses and deviate the light beam from the photocell. The output of the latter is recorded on a drum. The design features of the instrument, and its operation, are described and illustrated. A sample diagram illustrates the sensitivity.

K. J. De Juhasz, Germany

2278. Rayner, A. C., and Haliburton, W., Rotary device for producing a stream of uniform drops, *Rev. sci. Instrum.* **26**, 12, 1124–1127, Dec. 1955.

A rotary device was developed to produce uniform drops of liquids in the diameter range of 50 to 700 microns. A horizontally rotating blade detaches drops in a steady stream of regular trajectory, from a stabilized liquid mass fed under constant head through a stationary capillary. Design and operation of apparatus is described and illustrated, and performance characteristics with oil and aqueous test solutions are given. Drop size is calculated from the mass of drops emitted in a given interval at a known generation frequency. Variation in size of individual drops, electrostatic effects, and some uses for the machine are noted, such as delivering metered amounts of solutions to specified containers and surfaces. The investigation had the purpose of calibrating spray assessment techniques to deposit drops of known size on various sampling surfaces.

K. J. De Juhasz, Germany

2279. Fitzpatrick, H. M., and Harkleroad, M. F., A meter for continuous indication of dissolved air in water, *David W. Taylor Mod. Basin Rep.* 867, 1–19, Oct. 1954.

2280. Johnson, G. D., (condensed by), Symposium on laboratory testing of hydraulic turbine models in relation to field performance, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-124, 12 pp.

2281. Woods, L. C., On the lifting aerofoil in a wind tunnel with porous walls, *Proc. roy. Soc. Lond.* **242**, 1230, 341–354, Nov. 1957.

A continuation of author's laborious theoretical work [AMR **9** (1956), Rev. 1528] on the wall interference in wind tunnel with partly porous sides. The flow is subsonic and two-dimensional with a thin plane airfoil placed midway between the porous sides. This time the corrections to the lift and moment are calculated. Although any practical considerations such as tables or graphic representations are outside of author's concern, someone may find due interest. M. Sanuki, Japan

2282. Deitchman, S. J., A method for examination of store separation from aircraft through dynamic model testing at full-scale Mach number, *J. aero. Sci.* **24**, 4, 275–280, Apr. 1957.

The need for study of the motion of stores after launch or jettison from high-speed aircraft has led the designer to resort to dynamic model testing at full-scale Mach numbers as a direct analytical technique. Accordingly, it has been found useful to formulate a set of similarity laws for such testing for the cases most commonly encountered—i.e., freely falling bodies and fin or spin-stabilized powered projectiles. Consideration has also been given to obtaining model to full-scale similarity of the jet of a powered projectile, for study of its effect on the launching aircraft. Requirements for simulation of the effects of fuel in a full or partially full tank have been examined qualitatively. Some simulation errors that may be encountered have been examined and evaluated. From author's summary

2283. MacDermott, W. N., Preliminary test results with an arc-heated hypersonic wind tunnel at Mach numbers of 10 to 20, Proc. Fifth Midwestern Conf. Fluid Mech., Univ. of Mich., Apr. 1957, 224–237.

A hypersonic blow-down wind tunnel featuring arc-heating of supply air has been placed in test operation at the Arnold Engineering Development Center. Performance of the heater is suf-

ficient to provide true temperature simulation of hypersonic flight speeds, and the important real-gas effects in high-temperature aerodynamics can thus be investigated in this tunnel. Although longer than those in a shock tube, the run times are short and have necessitated several new instrumentation approaches. Results of a year's shakedown and instrument development are presented. The effects of real-gas behavior on isentropic nozzle expansions are discussed from both a theoretical and experimental standpoint. Preliminary pressure distributions and heat-transfer measurements on a typical model are presented.

From author's summary

2284. Harkness, J. L., A high stagnation temperature intermittent flow supersonic wind tunnel, Univ. Texas, Defense Res. Lab. DRL-406, 48 pp., Mar. 1957.

Report contains a description of the Defense Research Laboratory high-stagnation-temperature intermittent-flow supersonic wind tunnel. Preliminary design considerations are briefly outlined, while the bulk of the report concerns the detailed description of the resulting test facility. Each basic component of the wind-tunnel circuit is described along with the currently available instrumentation for model testing. The design and development work for the major components of the circuit have been described in other reports, with the exception of the working section of the tunnel. One section is included covering the design and fabrication of the supersonic nozzles in detail. This was considered consistent with a following section that presents the flow calibration data using the Mach number 5.0 nozzle. Mach number distributions in the supersonic test region as well as stagnation-temperature distributions in the stilling chamber and supersonic test region are included. From author's summary

2285. Tosti, L. P., Transition-flight investigation of a four-engine-transport vertical-take-off airplane model utilizing a large flap and extensible vanes for redirecting the propeller slipstream, *NACA TN* 4131, 35 pp., Dec. 1957.

2286. Jackson, G., The reduction to standard conditions of take-off measurements on turbo-jet aircraft, *Aero. Res. Counc. Lond. Rep. Mem.* 2890, 20 pp., 1957.

A reduction method intended for routine use is derived whereby the take-off distance required for a turbojet aircraft to clear a 50-ft screen under a specified set of standard conditions of air temperature and pressure, wind speed, aircraft weight and engine speed can be deduced from the distance measured in an aribtrary set of conditions. The method is basically similar to that used for piston-engined aircraft and the only information required in addition to that which can be observed is a numerical constant for the engine type. The method is shown to be not inconsistent with available experimental data. From author's summary

2287. Gough, M. N., Notes on correlation of model and full-scale spin and recovery characteristics, *AGARD Publications, Rep.* 27, 10 pp. + 2 tables + 8 figs., Feb. 1956.

Report calculates the usefulness of spin-tunnel results as an aid to piloting techniques in flight operations. A correlation of spin-tunnel and flight test results is presented. The need for better correlation through more detailed full-scale flight data and more qualified, accurate, and detailed pilot reports is emphasized. Included are notes to pilots emphasizing the value and limitations of existing spin-tunnel information.

From author's summary

2288. Marx, A. J., Some results of comparison of model and full-scale spinning tests, *AGARD Publications, Rep.* 26, iv + 6 pp. + 1 table + 2 figs., Feb. 1956.

Results are presented of comparison of wind-tunnel and full-scale spinning tests for the Fokker S-11 primary trainer. In free flight, under equivalent conditions, steady spins were observed with two different types of motion, while in the wind-tunnel tests only one of those types of motion had been recorded.

In general, agreement on the steady spin and recovery characteristics between wind tunnel and free flight is satisfactory. Finally, a comparison of yawing moment coefficients calculated from wind-tunnel and free flight tests is given.

From author's summary

2289. Wardlaw, R. L., and Templin, R. J., Preliminary wind tunnel test of a lifting fan in a two-dimensional aerofoil, *Nat. aero. Establ. Canad. LR* 207, 11 pp. + 9 figs., Sept. 1957.

2290. Leist, K., An experimental arrangement for the measurement of the pressure distribution on high-speed rotating blade rows, *Trans. ASME* **79,** 3, 617–626, Apr. 1957.

For several years past the research staff of the Institute for Turbomachines of the Aachen Technical University has carried out measurements on rotating turbine blading. This program is part of a comprehensive effort directed toward the experimental investigation of the three-dimensional flow through axial-flow turbomachines. From author's summary

2291. Ohigashi, S., Nakaizumi, T., Kashiwada, Y., and Hayashi, T., A new experimental method of scavenging process in two-stroke engine cylinder, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 397–400.

Thermodynamics

(See also Revs. 1872, 1873, 1874, 1875, 1879, 1882, 1884, 1885, 1961, 2233, 2236, 2279, 2316, 2318, 2319, 2337, 2348, 2360, 2366)

Book—2292. Wilson, A. H., Thermodynamics and statistical mechanics, New York, Cambridge University Press, 1957, xv + 495 pp. $9.50.

The approach of the physicist to the subject of thermodynamics has always involved a conviction that the principles of thermodynamics themselves represented a critically incomplete exposition of underlying phenomena. Only by relating thermodynamics to statistical mechanics and ultimately to quantum statistics is a treatment provided which is satisfactory to the physicist. The present work provides a comprehensive approach integrated in this manner. No sharp distinction is made between the thermodynamic analysis and the procedures of statistical mechanics. The methods of the latter field are introduced systematically and prove additional insight into thermodynamic phenomena as needed. Of the fourteen chapters, the first three are essentially a review of classical thermodynamics. The fourth examines the axiomatic foundations in a critical manner and the fifth similarly treats statistical mechanics. The sixth and eighth comprise applications of statistical mechanics to the determination of heat capacities and state equations for gases. The seventh develops the third law from both basic views. The tenth discusses electric and magnetic phenomena. Chapters 9, 11, and 12 pertain to equilibria of heterogeneous systems and to the thermodynamics of solutions and chemical systems. The final two chapters consider electrochemical systems and the thermodynamics of high polymers and alloys.

N. A. Hall, USA

2293. Jaynes, E. T., Information theory and statistical mechanics, *Phys. Rev.* (2) **106,** 4, 620–630, May 1957.

In view of the absence of a satisfactory foundation of statistical mechanics author suggests an alternate derivation which makes use neither of the microscopic equations of motion, nor of ergodic property and metric transitivity. The canonical distribu-

tion is established by the criterion that the entropy be a maximum (cf. J. C. Slater, "Introduction to chemical physics," McGraw Hill, 1939, p. 46). The entropy is taken as a basic concept borrowed from information theory. Statistics is interpreted in a subjective sense: the canonical distribution is the least biased estimate from incomplete knowledge. Reviewer believes that author went too far in discarding the physical content of statistical mechanics; e.g. his formalism does not distinguish states of thermodynamic equilibrium from those with frozen-in disorder. Yet, it is only in the former case that his entropy is related to heat quantity as $T\,ds = dQ$. L. Tisza, USA

2294. Brown, W. B., The statistical thermodynamics of mixtures of Lennard-Jones molecules, I. Random mixtures; II. Deviations from random mixing, *Phil. Trans. roy. Soc. Lond.*(*A*) **250,** 976, 175-246, Oct. 1957.

Paper describes a development in the statistical theory of mixtures of spherical molecules. It is shown that, for a mixture of molecules interacting according to the Lennard-Jones inverse-power potential, the assumption of random mixing is sufficient to relate the thermodynamic properties of the mixture *exactly* to those of a reference substance, after the manner of the law of corresponding states; and it is proved in an appendix that only the Lennard-Jones form of the potential energy function leads to this simple result. If the molar configurational Gibbs function of the reference substance is $G_0(T, P)$, then that of the random mixture is

$$G(T, P, x) = f_x G_0(T/f_x, Pb_x/f_x) - RT \ln b_x + RT \sum_\alpha x_\alpha \ln x_\alpha,$$

where x_α is the mole fraction of component α, and where f_x and b_x are dimensionless functions of the composition involving the characteristic molecular energy and size constants for the interactions of the various species.

This equation is used to discuss the phenomena peculiar to mixtures of substances under the headings: mixing effects, phase equilibria, and critical phases. A necessary condition on the intermolecular forces for azeotropy to occur in binary mixtures is derived in a simple form which can be appreciated intuitively; the possibility of a lower critical solution point in these mixtures is examined and shown to be unlikely; and the difficulties in the way of deriving the critical or plait-point curve are outlined. The liquid mixing properties of the system carbon monoxide + methane are calculated from the theory, and shown to be in fair agreement with experiment.

The Gibbs function of the mixture is analyzed by a Taylor-series expansion, and it is shown that the first-order terms of the present theory are identical with those of the theory of conformal solutions, due to Longuet-Higgins, but that the second-order terms involve approximations, resulting from the assumption of random mixing. Expanded forms of the mixing functions are derived for the special class of binary mixtures whose characteristic energy and size constants obey geometric and arithmetic mean rules respectively, and the signs of these functions are discussed.

From author's summary

2295. Zemansky, M. W., Fashions in thermodynamics, *Amer. J. Phys.* **25,** 6, 349-351, Sept. 1957.

It is pointed out that thermodynamics is a useful subject in widely varying fields, such as engineering, chemistry, and physics. It is, however, used in such different ways by scientists in these fields that one group hardly recognizes what the other is doing. Some of the controversies in the nomenclature of thermodynamics are mentioned and some of the changing styles in thermodynamics are explained in terms of the thermocouple. Some unfortunate tendencies in the teaching of thermodynamics are deplored. Author ends with a tribute to many of his former students. From author's summary

2296. Gustafson, W. A., and Krzywoblocki, M. Z., On multiplicity theorems and an exact solution in diabatic flow, I, *Acta Phys. Austr.* **11,** 2, 131-146, 1957.

2297. Knuth, E. L., Thermal conductivity and Prandtl numbers for nonpolar polyatomic gases at high temperatures, *Jet Propulsion* **27,** 12, 1262-1263, Dec. 1957.

2298. Holmes, A. G., and Hollitch, R. S., A steam properties program for medium and large computers, ASME Ann. Meet., New York, N. Y., Dec. 1957, Pap. 57-A-278, 8 pp.

Data from "Thermodynamic properties of steam" by Keenan and Keyes were fitted by polynomials in which enthalpy is a function of pressure and entropy. The coefficients required are tabulated. A major portion of the steam-table range is covered.

J. H. Keenan, USA

2299. Madsen, J., and Pfeifer, W. J., Jr., Interpolated tables for enthalpy of superheated steam, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-201, 5 pp.

Values of enthalpy from "Thermodynamic properties of steam" by Keenan and Keyes were interpolated by means of a digital computer to obtain values at intervals of 1 F to 1600 F and 2 psi to 2500 psia. The interpolated tables have been deposited as Document Number 5280 with the A.D.I. Auxiliary Publications Project, Photoduplication Service, Library of Congress.

J. H. Keenan, USA

2300. Steltz, W. G., and Silvestri, G. J., The formulation of steam properties for digital computer application, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-109, 6 pp.

The equations for volume, enthalpy, and entropy as functions of pressure and temperature as given in "Thermodynamic properties of steam" by Keenan and Keyes were programmed for an IBM 704 computer. A small unexplained deviation from values given in the steam tables was eliminated by means of correction terms.

J. H. Keenan, USA

2301. Schnackel, H. C., Formulations for the thermodynamic properties of steam and water, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-105, 8 pp.

The equations for volume, enthalpy, and entropy as functions of pressure and temperature as given in "Thermodynamic properties of steam" by Keenan and Keyes are truncated by omission of a term in order to obtain convenient relations for use on computers. Methods of application and errors are discussed.

J. H. Keenan, USA

2302. Ryley, D. J., Supersaturation in steam expanding from a low initial quality, *Engineer, Lond.* **203,** 5285, 708-712, May 1957.

2303. Jackson, T. W., and Thomas, F. A., Equipment for the study of the viscosity of steam, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-222, 7 pp.

Paper describes the equipment built at the Georgia Institute of Technology for use in determining the viscosity of steam at temperatures between 212 and 1200 F and at pressures up to 5000 and possible 10,000 psi. It also briefly describes the senior author's past experience in determining the viscosity of steam by the annular transpiration method, which is the system utilized in this investigation. The present work is being undertaken for The American Society of Mechanical Engineers. It is part of a general steam research program being conducted by an ASME Technical Committee on Properties of Steam. From authors' summary

2304. Jarry, R. L., All-metal apparatus for the determination of the density of liquefied gases, *Rev. sci. Instrum.* **28,** 8, 641–642, Aug. 1957.

An all-metal apparatus designed for density measurements on liquefied gases is described. The metal construction enabled its use with corrosive materials, and also allowed measurements to be made to moderate pressures. It consists of a pycnometer, temperature control device, and gas-handling system. While this apparatus was particularly designed for density work it was used for vapor pressure determinations with slight modification. The design and construction is detailed and its use with liquid fluorine outlined. From author's summary

2305. Zimmerman, R. H., Beitler, S. R., and Darrow, R. G., A method for predicting supercompressibility factors of natural gases, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57–A–69, 4 pp.

A method is developed for calculating the proper constants in a series of equations describing the composition of a natural gas mixture. The supercompressibility factor can be defined as a function of reduced pressure and temperature. This, then, allows the calculation of supercompressibility of natural gas as it flows through a pipeline. Reviewer believes the use of the word prediction is a misnomer which might better read calculation. The analysis would also be greatly enhanced by the application of statistical methods. For engineering purposes, however, the method is probably accurate enough. J. H. Davidson, USA

2306. Buthod, P., How to estimate pressure drop in heaters, *Oil and Gas J.* **55,** 26, 111–118, July 1957.

A family of enthalpy lines is superimposed on the phase (pressure-temperature) diagram of the stock being vaporized. This makes it possible to run a continuous heat balance on the heater while making a graphical integration to evaluate the pressure-versus-length curve. From author's summary

2307. Hoxton, L. G., "Ratio of the specific heats" and thermodynamics, *Amer. J. Phys.* **25,** 7, 460–462, Oct. 1957.

Attention is directed to certain adiabatic equations, which are deducible from definitions independent of thermodynamic principles. The facts appear to be little known; textbooks and other writings disagree about them. The very simple proofs discussed here result in economy of thought with attendant benefits to both student and director. From author's summary

2308. Probstein, R. F., Inversion of the Prandtl–Meyer relation for specific-heat ratios of 5/3 and 5/4, *J. aero. Sci.* **24,** 4, 316–317, Apr. 1957.

2309. Tsu, T. C., and Beecher, D. T., Thermodynamic properties of compressed water, ASME Fall Meet., Hartford, Conn., Sept. 1957. Pap. 57–F–10, 5 pp.

An account is given of preparation of an enthalpy-entropy chart (1 mm. = 0.2 Btu/lb and 0.002 Btu/lb F abs) for compressed liquid water, 32 F to critical temperature and saturation pressure to 6000 psia. The chart is based on the "Thermodynamic properties of steam" by Keenan and Keyes, supplemented by the thermodynamic charts of Ellenwood and Mackey, the specific-heat data of Koch, and the P-V-T measurements of Smith and Keyes. Copies of the chart may be purchased from the A.S.M.E.

J. H. Keenan, USA

2310. Reamer, H. H., Richter, G. N., DeWitt, W. M., and Sage, B. H., Apparatus for the experimental study of the thermodynamic properties of water, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57–A–266, 12 pp.

As a part of an investigation of the properties of water at elevated temperatures and pressures, a study of the Joule-Thomson coefficient and the isothermal enthalpy-pressure derivative of steam has been undertaken. This experimental program is directed to the study of these coefficients at about temperatures between 400 F and 1500 F and at pressures up to 15,000 psi, or to a specific weight of the fluid such that the coefficients approach the inversion point. Some measurements in the region of negative Joule-Thomson coefficient may be undertaken.

From authors' summary

2311. Farber, E. A., and Glickstein, M. R., Effects of junction manufacture on thermocouple EMF generation, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–135, 6 pp.

2312. Cockshutt, E. P., Dual-operation powerplants for vertical take-off transport aircraft: A preliminary analysis of several gas-turbine cycles, *Nat. aero. Establ. Canad. LR* 201, 19 pp. + 5 figs., July 1957.

2313. Govier, G. W., Radford, B. A., and Dunn, J. S. C., The upwards vertical flow of air-water mixtures. I. Effect of air and water rates of flow pattern, holdup and pressure drop, *Canad. J. chem. Engng.* **35,** 2, 58–70, Aug. 1957.

The elementary thermodynamics and the flow pattern terminology of the upward vertical flow of gas-liquid mixtures is reviewed and new terminology is proposed.

Data on the upward vertical flow of air-water mixtures in a smooth bore 1.025-in. I.D. tube are presented for a range of nine water rates from 0.00040 to 0.0421 cu. ft. per sec and for air-water volume ratios under flow conditions from 0 to 348. The properties of the gas and liquid phases were held constant through the maintenance of constant average flowing pressure and temperature at 36.0 psia and 70 F.

A correlation of the data based upon the thermodynamic analysis is presented. The correlation enables the prediction of flow pattern, pressure drop, and holdup ratio for gas and liquid rates within the range tested but is restricted as to tube diameter and liquid and gas phase properties.

From authors' summary

2314. Hecht, C. E., Equation of state for binary fluid mixtures, Univ. Wisc. Nav. Res. Lab.,(5), ONR-24, 20 pp., Aug. 1957.

A perturbation technique is used to develop an equation of state for binary fluid mixtures. The resulting equations can be used to calculate compressibility factors for gaseous mixtures at high temperatures. The results are in good agreement with experimental values. M. Gerstein, USA

Heat and Mass Transfer

(See also Revs. 1854, 1856, 1863, 1870, 1941, 1948, 2027, 2172, 2180, 2181, 2227, 2228, 2297, 2302, 2311, 2313)

Book—2315. Kay, J. M., An introduction to fluid mechanics and heat transfer, New York, Cambridge University Press, 1957, xvi + 309 pp. $7.

The content includes essentially the following topics: Introduction and definitions; equations of continuity, momentum, energy; flow in pipes and channels; pumps and compressor; heat conduction; heat exchangers; Reynolds analogy and Taylor-Prandtl improvement; Navier-Stokes equation; boundary layers; mixing-length theory and universal velocity profile in turbulent flow; mass transfer; forced convection; one-dimensional compressible flow; open channel flow; fluid flow with solid suspension; flow through porous media; condensation and evaporation.

The treatment is, in general, elementary and brief, sometimes superficial. This is somewhat excusable in view of the large coverage within 300 pages. It is explicitly stated that thermodynamic

subleties are not to be expected, but still there is no justification to say that "it is impossible to give a satisfactory definition of temperature without bringing in the concept of heat, and... equally impossible to give a satisfactory definition of heat without bringing in the concept of temperature." Generally speaking, the book is of good standing among those of a similar nature.

L. S. Dzung, Switzerland

2316. Powell, R. L., Roger, W. M., and Coffin, D. O., An apparatus for measurement of thermal conductivity of solids at low temperatures, *J. Res. nat. Bur. Stands.* **59,** 5, 349–355, Nov. 1957.

Thermal conductivity is determined by axial heat flow through a long cylindrical sample. Test is made in an evacuated cylinder mounted inside a suitable cryogenic liquid bath. A cylindrical thermal shield surrounds the sample. The shield is heated electrically so as to maintain a thermal gradient approximating that of the sample. Heat is supplied to the bottom of the sample by means of copper blocks electrically heated. Samples are about 20 cm long, but diameter is varied so as to give suitable heat flux. Metal sample rods are 0.367-cm diam; plastic 2.54-cm diam.

Tests give consistent results with both large and small temperature gradients of samples, usually deviations from average curve less than 1% at liquid helium range, 1/2%, at liquid nitrogen range. With very high conductivity and very low conductivity materials, in inaccuracies are greatest—about 5%. Results are given for polytetrafluoroethylene and high-purity copper.

D. Aronson, USA

2317. Sutton, G. W., On one-dimensional heat conduction with an arbitrary heating rate, *J. aero. Sci.* **24,** 11, 854–855 (Readers' Forum), Nov. 1957.

The one-dimensional nonsteady conduction of heat in an infinitely long plate of finite thickness is considered when one boundary is insulated and the other is subjected to an arbitrary heating rate that is a function of time. The plate is assumed to be initially at a uniform temperature.

If the heat rate is expressible as a polynomial in time (up to the fifth degree) then the author deduces a series expression which converges rapidly for small times and which utilizes the previously published design charts of Kaye and Yeh. For large times a second series is developed which converges rapidly, and calculated values of the coefficients are tabulated.

If a polynomial representation of the heating rate is not possible, then a "simple quadrature" method is proposed. Reviewer feels that the quadrature may not always be simple—depending on the nature of the function. A. J. Chapman, USA

2318. Hirschfelder, J. O., Generalization of the Eucken approximation for the heat conductivity of polyatomic or chemically reacting gas mixtures, Univ. Wisc. Nav. Res. Lab. (5), ONR 25, 22 pp., Sept. 1957.

2319. Nehring, O., Determination of heat conduction coefficient in plastics (in German), *Technik* **11,** 12, 821–824, Dec. 1956.

2320. Budrin, D. V., A hydrostatic integrator for solving the differential equation of thermal conductivity for varying temperature relationships of the thermophysical properties—coefficient of thermal conductivity and heat capacity (in Russian), *Trudi. Uralsk. politekhn. in-ta* no. 53, 22–41, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7576.

This integrator enables mechanization of the calculation work for the approximate solution, by the method of finite differences, of the differential equation of heat conductivity for any relationship between the coefficient of heat conductivity and volume heat capacity, and the temperature. The integrator works on the principle of communicating vessels. This instrument has been successfully used for a number of years to solve complicated problems of heat engineering in the Glass Institute and Fuel Utilisation Institute. K. K. Vasilevskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2321. Gross, J. F., and Van Ness, H. C., A study of laminar-flow heat transfer in tubes, *AIChE J.* **3,** 2, 172–175, June 1957.

The measurement of local laminar-flow heat-transfer coefficients is made for liquids, flowing in a stainless steel vertical tube heated by passing a high electric current directly through the tube wall, and so giving a constant rate of heat input with length. The radial temperature gradient at the wall is deduced from axial gradient of the bulk temperatures and data for local heat transfer are correlated by means of an empirical equation.

C. Codegone, Italy

2322. Hunziker, R. R., Heat transfer in turbulent pipe flow, Reed Research, Inc., Proj. RR-1167-B, Contract AF 18 (603)-104, 77 pp., Apr. 1957.

This is a detailed presentation of calculations on turbulent heat transfer in a circular pipe and between parallel plates. The problems are rendered determinate by postulates like those used by Pai [AMR **6** (1953), Revs. 3156, 3969].

Although this computation may be of engineering use, it makes no contribution to the basic problem of turbulent heat transfer. In his introductory discussion the author even misinterprets the results of Laufer's turbulent pipe measurements in order to claim that the "laminar sublayer" is a fiction. Of course the notion of a laminar sublayer, lucidly explained by G. I. Taylor in 1916 [*Aero. Res. Counc. Lond. Rep. Mem.* 272], follows simply from the no-slip condition and the continuity equation. Since the normal velocity starts out quadratically from the wall [cubically in parallel mean flows: see Elrod, *J. aero. Sci.* **24,** no. 6, June 1957], the turbulent (Reynolds) stress starts cubically (quartically in parallel flows). Hence there must be a finite layer near the wall in which the turbulent shear stress is negligible compared with the laminar shear stress. S. Corrsin, USA

2323. Nonweiler, T., Skin temperatures and heat transfer over wedge wings at extreme speeds, *Coll. Aero. Cranfield Rep.* 105, 30 pp. + 8 figs., Aug. 1956.

By paying special attention to the wing design and altitude of flight, it is possible to insure that the highest temperature reached at the leading edge of the wing of an aircraft, in level flight at speeds of the order of the circling velocity, need be no more than about 1000C. The nose temperature will reach its highest value at a speed equal $(2/3)^{\frac{1}{2}}$ the satellite velocity. Formulas and charts are presented to enable the actual skin temperature close to the nose to be predicted, for a wedge-shaped wing, in terms of skin thickness and conductivity.

From author's summary by M. H. Bertram, USA

2324. Kestin, J., and Maeder, P. F., Influence of turbulence on transfer of heat from cylinders, *NACA TN* 4018, 78 pp., Oct. 1957.

It has been suspected for some time that the transfer of heat between a body and a stream of fluid is influenced by the turbulence in the stream. Previous experiments, while confirming that such an influence existed, did not distinguish between changes in position of the transition point and a genuine change in local heat-transfer rates. Authors' experiments were designed to examine this problem carefully. The rates of heat transfer from a long circular cylinder with its axis perpendicular to an airstream were measured in a low-speed wind tunnel with and without boundary-layer trip wires attached to the cylinder and with varying intensities of stream turbulence as generated by grids of bars placed near the entrance to the tunnel working section. With the trip wires in

place, substantial changes in heat transfer rates were detected; for example, at a Reynolds number of 1.6×10^5 an increase in turbulence intensity from 1.2% to 2.6% caused an increase of 27% in the Nusselt number. The cylinder diameter was 10.6 cm and the longitudinal scale of the turbulence was roughly 0.2 cm. (Some of the measurements were made rather close to the grid—about 24 mesh lengths away—where, reviewer suspects, the turbulence had not yet become homogeneous, as evidenced by the longitudinal velocity correlation becoming negative for points separated by about 1 mesh length.)

Authors suggest that the main influence of the stream turbulence is to cause oscillations in the flow in the boundary layer on the cylinder, and thereby affect the temperature and, to a different extent, the velocity profiles. While agreeing that such an explanation is valid for a laminar flow, reviewer believes that a more important mechanism of increased heat transfer in turbulent flow is the alteration in the intensity of the large eddies in the boundary layer caused by the entrainment of turbulent fluid from the main stream.

Paper is valuable and provides a caution against accepting measurements of heat transfer, such as the otherwise detailed ones of Hilpert, without a description of the turbulence in the main stream. P. R. Owen, England

2325. Diaconis, N. S., Wisniewski, R. J., and Jack, J. R., Heat transfer and boundary-layer transition on two blunt bodies at Mach number 3.12, *NACA TN* 4099, 31 pp., Oct. 1957.

Local rates of heat transfer were measured on a hemisphere-cone-cylinder and a 120° cone-cylinder in a wind tunnel by precooling the bodies and recording the distribution of surface temperature when exposed to an airstream at a Mach number of 3.12. The Reynolds numbers in the experiments were of the order of 10^6 per inch (body diameter 1.75 in.). Good agreement with Reshotko's theoretical predictions of the heat-transfer rate was obtained in regions of laminar boundary-layer flow, except near the stagnation point on the 120° cone-cylinder where comparison between theory and experiment was hampered by a lack of accurate knowledge of the Mach number gradient there. The effect of roughening the surface of the hemisphere-cone-cylinder to an extent of about 10^{-4} in. was to increase the heat-transfer rates without inducing transition to turbulence on the hemispherical portion.

Transition to turbulent flow was located from the heat-transfer data by the position on the surface of the body at which the heat-transfer rate increased abruptly. It was found that the Reynolds number at transition increased with increasing wall temperature, as authors point out, contrary to the predictions of stability theory (and experiment). P. R. Owen, England

2326. Gvozdkov, N. M., The approximate equations of motion for a thin layer of a viscous, compressible fluid with heat exchange (in Russian), *Trudi Voronezhsk. in-ta* **27,** 14–19, 1954; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7529.

The required functions (velocity and pressure components, etc.) are expanded in series for powers of $1/R$ in the case of small values of the Reynolds number, and by powers of $1/\sqrt{R}$ for large values of R. These expansions are substituted in the hydrodynamic equations, terms with like powers of R are equated, thus obtaining systems of equations determining the successive approximations.

The work contains equations for the required functions in the zero and first approximations. G. M. Bam-Zelikovich

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2327. Taylor, C. F., and Toong, T. Y., Heat transfer in internal-combustion engines, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-17, 21 pp.

Basic heat-transfer relationships for one-dimensional forced convection are applied to the more complicated problem of heat transfer from the gas side to the cooling media in internal-combustion engines. Validity of the application is supported by experimental investigations in three geometrically similar spark ignition engines and a Comet diesel engine. The results are summarized, for the engines tested and 15 commercial engines of different sizes and design, by a plot of the Nusselt number based on the over-all heat-transfer factor versus the Reynolds number referred to the gas side. The analysis is based on the measurement of average surface temperatures at one point on the gas side and one on the cooling side of the cylinder head. Nusselt has shown [*Forschungsarbeiten* no. 300, 1928] that the gas film transfer factor is greatly influenced by the gas pressure. This fact may be of considerable importance in the location of a thermocouple used to measure the temperature on the gas side. If the influence of pressure is properly accounted for in the determination of the mean over-all transfer factor, the accuracy of ± 20% reported by the authors may be appreciably increased. C. J. Vogt, USA

2328. Creager, M. O., Effects of leading-edge blunting on the local heat transfer and pressure distributions over flat plates in supersonic flow, *NACA TN* 4142, 54 pp., Dec. 1957.

Surface pressures and heat-transfer rates were measured on flat plates with various values of blunting for a Mach number of 4 and Reynolds numbers per inch of 2380 and 6600. Surface pressures were correlated for a wide range of variables by a linear combination of terms obtained from shock-wave boundary-layer interaction theory and blast-wave theory. A method was developed to correlate local Reynolds numbers from the present data with data from other sources covering a wide range of test conditions.

From author's summary

2329. Ruggeri, R. S., and Lewis, J. P., Investigation of heat transfer from a stationary and rotating conical forebody, *NACA TN* 4093, 15 pp. + 1 table + 13 figs., Oct. 1957.

Experimental convective heat transfer was determined for a conical forebody (15° half-angle) for free-stream velocities up to 400 fps, rotational speeds up to 1200 rpm, angles of attack of 0° and 6°, and for heating conditions of uniform surface temperature and unifrom heater input power density. For the turbulent region, the results were in closer agreement with values predicted for two-dimensional bodies than with those predicted for a cone. Effects of rotation were insignificant. For the stationary spinner at 6° angle of attack, the heat-transfer coefficients were 6 to 13% greater on the lower surface than on the upper surface. Early boundary-layer transition occurred for all conditions investigated.

From authors' summary

2330. Siegel, R., Transient free convection from a vertical flat plate, *ASME Trans.* **80,** 2, 347–359, Feb. 1958.

Two important problems are analyzed by boundary-layer methods. Both apply to a vertical flat plate of infinite width and semi-infinite length which is initially at ambient temperature in a quiescent fluid. In the first, the plate is suddenly raised to a uniform high temperature; in the second, it suddenly begins to produce a uniform heat flux at its surface. Author cites as an important application the possible behavior of nuclear reactor fuel elements in the event of coolant circulation failure. By introducing several of the usual boundary-layer velocity and temperature profiles, the equations of motion and energy can be integrated to yield partial differential equations for boundary-layer thickness and characteristic velocity as functions of the vertical distance and the time. Since these are hyperbolic, they can be treated by the method of characteristics. Author shows that the two characteristics through the origin on a time distance plane have special significance. One predicts the delay before the initial, purely local convection is affected by conditions at the leading edge of the plate. The other indicates the time required to reach the steady state at a given point. The as-

sumed temperature and velocity profiles are compared graphically with known exact solutions for the initial purely local case and the final steady-state motion. The comparison is quite good for all temperature profiles but only approximate for the velocity profiles The end result of the analysis, the variation of heat-transfer coefficient with time, shows the expected rapid drop from a high initial value in the early stages. However, the coefficient apparently goes through a minimum before settling down to the steady-state value. As the author points out, this minimum may result from the approximate method of the analysis; it deserves to be checked experimentally.

Reviewer finds this to be a well thought out and careful analysis. The use of the method of characteristics in this rather different application is interesting and leads to significant physical conclusions. R. R. Hughes, USA

2331. Sparrow, E. M., and Gregg, J. L., Similar solutions for free convection from a nonisothermal vertical plate, *ASME Trans.* **80,** 2, 379–386, Feb. 1958.

Authors analyze laminar free convection for two types of surface temperature variations; proportionality to a power of the distance from the leading edge, x, and exponential increase or decrease with x. Both lead to velocity and temperature profiles having similarity with respect to x. This permits transformation to ordinary differential equations, which are solved numerically for Prandtl numbers of 0.7 and 1.0, and a number of values of the arbitrary constants in the wall-temperature functions. A few of the resulting profiles are unusual; authors point out that these correspond to uncommon or physically impossible boundary conditions. Nusselt-Grashof relations obtained for the reasonable cases show a strong dependence on the nature of the wall-temperature function.

Reviewer thinks this is a sound analysis of a rather general free convection model. It should have valuable applications in design problems. However, in fitting the design problem to the model, care must be used; the engineer must be certain that all the boundary conditions apply to his particular problem. Moreover, the limitation to laminar motion must be kept in mind.
R. R. Hughes, USA

2332. Ostrach, S., and Thornton, P. R., On the stagnation of natural-convection flows in closed-end tubes, *ASME Trans.* **80,** 2, 363–366, Feb. 1958.

Paper presents an interesting and valuable extension of Lighthill's analysis of laminar free convection in tubes [AMR **7** (1954), Rev. 2294] to cases with linear variation in wall temperature along the tube. Following Lighthill, equations of motion and energy are integrated across the tube, using assumed velocity and temperature profiles. Parameters are the usual product of the Rayleigh number with the diameter/length ratio and a modified Rayleigh number involving the temperature gradient. Method is approximate, but permits algebraic solution, and results seem reasonable. Reviewer would like to see them checked by adapting method of Sparrow and Gregg [see preceding review], to cylindrical coordinates. Authors' analysis is well presented with one rather annoying exception; the symbol β is defined and used as the volumetric expansion coefficient in the early section of the analysis. Then in the final solutions (Eq. (17)) a new β is introduced without any definition; readers familiar with Lighthill's nomenclature can identify it as an arbitrary coefficient, but others will probably be confused.

The results show that a positive temperature gradient can increase the effective, or critical, length of the convective motion; this has great practical significance, since cooling tubes with lengths greater than the critical value have layers of stagnant hot fluid at the bottom. Reviewer feels this increase in generality over Lighthill's problem will make the design of free convection cooling tubes for turbine blades much easier. Still more flexibility might result from considering the variation in centrifugal acceleration along the tube. Another point for study is the stability of this system; the eigenvalue behavior discussed by Lighthill implies similarities to the system studies by Malkus [AMR **8** (1955), 3907–3908]. R. R. Hughes, USA

2333. Nakagawa, Y., Apparatus for studying convection under the simultaneous action of a magnetic field and rotation, *Rev. sci. Instrum.* **28,** 8, 603–609, Aug. 1957.

The equipment described is designed to use mercury as the working fluid in order to examine the dependence of the critical Rayleigh number for the onset of instability on the prime nondimensional magnetic and rotation parameters. The mode of the subsequent convection can also be studied. The significant nondimensional parameters can be varied over large ranges.

A few examples of typical results obtained from this apparatus are discussed. S. Ostrach, USA

2334. Bevans, J. T., Gier, J. T., and Dunkle, R. V., Comparison of total emittances with values computed from spectral measurements, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-29, 10 pp.

Spectral and total emittances have been measured for materials exposed to various oxidation conditions (total of 25 samples). The total emittance values computed from the spectral data have been found to compare favorably with the measured total values. The experimental techniques utilized for both types of determinations are described and the effect of temperature, sample preparation, and experimental errors are discussed relative to the differences obtained in the results. From authors' summary

2335. Bartas, J. G., Temperature profiles in radiation-cooled turbine wheels, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-122, 13 pp.

A method is presented for determining the steady-state temperature gradient in a turbine wheel subject to restricted boundary conditions. The turbine wheel received heat only by conduction from the turbine blades and loses heat only by radiation to a constant-temperature environment. From author's summary

2336. Chiarulli, R., and Dressler, R. F., Condensation interfaces in two-phase flows, *J. appl. Phys.* **28,** 9, 990–997, Sept. 1957.

Consideration is given to the problem of vapor condensation for liquid and vapor flow in a channel. The system is idealized by assuming that an interface separates the vapor and liquid phases of the fluid with concentrated friction, heat removal, and cold liquid injector mechanism at the interface. Specific calculations are carried out for two cases of steam-water combinations. In the first, condensation is brought about by heat removal alone. In the second case, the condensation is effected by means of cold water entering through the entrance section with the original steam. Thermodynamic considerations are shown to produce upper and lower bounds on the values of the cooling parameters.
L. Lapidus, USA

2337. Balekjian, G., and Katz, D. L., Heat transfer from superheated vapors to a horizontal tube, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-27, 18 pp.

Experimental data are presented for Freon 114 (superheat, 0-180 F) and steam (superheat, 109-184 F) condensing on a 3/4-in. tube, 2 ft long. Authors conclude that, in the absence of excessive splashing of condensate, superheat lowers heat flux and condensing load (1 lb/hr/ft^2) and increases depression of condensate-surface temperature below that of the saturated vapor. Schrage's equations for mass transfer at an interface were simplified and used to correlate condensing load with superheat. Authors recommend that their correlation be used for applications involving film condensation of superheated vapors on outside of horizontal tubes. Inter-

facial film coefficients of heat transfer between the superheated vapor and the condensate surface are reported, based on computed surface temperatures. L. Helander, USA

2338. Research into boiler circulation theory. Parts I, II *Engineer, Lond.* **204,** 5295, 81–83, July 1957; **204,** 5296, 112–114, July 1957.

Paper describes an apparatus used on a research project undertaken by Cambridge University and sponsored by the Water-Tube Boilermakers Association, whose objective is to establish experimental data about the pressure drop and flow conditions of a steam-water mixture flowing along heated and unheated tubes up to the critical pressure of steam. The effects of pressure, heat input rate, internal tube diameter, water velocity, and dryness fraction of the steam-water mixture on pressure drop are being studied.

The apparatus passes water in the saturated condition from a steam drum through a 24-ft single-pipe test section equipped with heaters designed to permit heating over 8-ft, 16-ft, and 24-ft lengths. This allows steam generation to take place at the test section inlet and the pressure drop of the water-steam mixture to be measured along the testing length.

Preliminary tests have been completed and first full tests are now in progress.

This research project will offer the possibility of becoming better acquainted with the effects of "bubble slip" on pressure drop at pressures used in industrial plants.

J. Schoenherr, USA

2339. Rohsenow, W. M., Heat transfer with boiling, *Medd. Varmestromsgruppen* **2,** 4, 48 pp. + 43 figs., 1956.

Paper is a fine survey of experimental data, hypothesis on heat transfer mechanism, and correlations for various types of evaporation. Theory of bubbles formation in pure liquid and in liquid with dispersed gas particles, based on thermal fluctuation of molecules, is plainly explained, and values for equilibrium and critical size of vapor nucleus are derived. Then heterogeneous nucleation on heating surface, growth and motion of bubbles are studied and effects of various liquid properties and surface conditions are briefly discussed. Equations for bubble Nusselt number and for its modification as function of *Re* and *Pr* for pool-boiling are confronted with experimental data, and some correlations for forced boiling are added. Finally, conditions under which burnout point occurs are explained.

Paper is accompanied by many (more or less distinct) instructive diagrams and by an extensive bibliography of western literature. O. Mastovsky, USA

2340. Siemes, W., and Guenther, K., Gas dispersion in liquids through nozzles in high rates of flow (in German), *Chem.-Ing.-Tech.* **28,** 389–395, 1956.

When injecting a gas jet from a nozzle into a liquid, gas bubbles of different sizes are produced. Charts can be made up to describe the distribution of sizes, and of other derived quantities, of the bubble multitude. In the present investigation such distribution curves were determined for varying nozzle diameters, rate of gas flow, liquid viscosity, and boundary surface tension. The specific surface (i.e., total surface area of the bubbles divided by the total volume) can be regarded as the characteristic quantity; some rules have been found to estimate this quantity. Experimental set up comprised gas meter, manometer, air pipe topped by interchangeable nozzle, water tank with transparent sides, and camera with flash lamp arrangement. The flash photos of the ascending gas bubbles were evaluated according to bubble sizes, the results tabulated and represented in spectrum curves. This investigation is a continuation of a previous project; former results have been published in previous reports given in the references. K. J. De Juhasz, Germany

2341. Siemes, W., and Kauffmann, J. F., Periodic generation of bubbles in nozzles (in German), *Chem. Engng. Sci.* **5,** 127–139, 1956.

The volumes of gas bubbles, generated at small gas velocities on vertical, circular nozzles in liquids, were measured by using a stroboscope. Variables investigated were: gas velocity, liquid density, surface tension and viscosity, and diameter and wall thickness of the nozzles. It was found that the formation of gas bubbles in liquids of high and low viscosity occurs according to two different mechanisms. For the two ranges of viscosity two empirical equations were developed for calculating the volumes of the gas bubbles. Nozzle diameters varied between 0.35 to 1.95 mm, the liquid density between 0.7 to 1.8 g/cm^3, surface tension between 28 to 73 dyn/cm, and viscosity between 0.4 to 800 cP. The volume of the bubbles was determined from the measured rate of air flow and the stroboscopically determined number of bubbles. Experimental equipment for insuring reproducible and consistent conditions is described in detail. Periodic bubble formation occurred at a flow rate of a few cm^3/ sec; at a flow rate of 10 to 100 cm^3/sec the continuous gas stream entered the liquid and then broke up into drops of various sizes.

K. J. De Juhasz, Germany

2342. Leppert, G., Costello, C. P., and Hoglund, B. M., Boiling heat transfer to water containing a volatile additive, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-81, 8 pp.

Aspects of local boiling in forced circulation when the boiling fluid contains small percentages of alcohol are discussed. Particular emphasis is placed on the improvement in smoothness of boiling and in the decrease of average bubble size when the additive is present, as contrasted with boiling distilled water. Experimental results, including photographs, are presented for surface boiling from the outside of a cylindrical stainless steel tube placed normal to the flow. Data are also presented for the subcooled boiling of distilled water, and comparisons are made with correlations from the literature. From authors' summary

2343. Leadon, B. N., Scott, C. J., and Anderson, G. E., Mass transfer cooling at Mach number 4.8, *J. aero. Sci.* **25,** 1, 67–68, Jan. 1958.

2344. Parsons, D. H., One-dimensional diffusion with the diffusion coefficient a linear function of con- ration: reduction to an equation of the first order, *Quart. appl. Math.* **15,** 3, 298–303, Oct. 1957.

Second-order equation describing transient one-dimensional diffusion from an initially sharp boundary is reduced by suitable substitutions to first-order equation. Mathematical properties of solution and a method of obtaining numerical solutions are discussed. No numerical results are given. E. L. Knuth, USA

2345. Green, L., Jr., Heat, mass, and momentum transfer in flow through porous media, ASME-AIChE Heat Trans. Conf., University Park, Pa., Aug. 1957. Pap. 57-HT-19, 10 pp.

At low speeds, porous media may be described by one characteristic length, the flow resistance being proportional to speed and viscosity. At faster flow rates, an inertial effect appears, proportional to the square of the speed, depending on a new geometrical parameter. The two length parameters of the medium are theoretically expressed as a function of porosity and specific surface. Parameter ratio permits the definition of a Reynolds number as a function of which the friction factor, heat-transfer factor, mass-transfer factor are written. Comparison of experimental results obtained with various media shows a general correlation be-

tween fluid friction and heat or mass transfer. The data deviate slightly from the quadratic law.

Exchanges occur at molecular scale, except in coarse structures where a real turbulence appears, with abrupt transition.

More precise heat-transfer measurements are necessary; measurements by transient technique are affected by boundary losses, by nonexact knowledge of entering fluid temperature, etc.

A. E. Brun, France

2346. Handlos, A. E., and Baron, T., Mass and heat transfer from drops in liquid-liquid extraction, *AIChE J.* **3,** 1, 127–136, Mar. 1957.

Mass and heat-transfer rates in extraction are studied theoretically and experimentally for the practical range of the variables involved. For the particular but typical case of liquid drops moving through another liquid a simple correlation for the over-all mass transfer coefficient is presented, which holds with a probable error of 20%. Included are systems in which the rate is limited by either coefficient, as well as systems in which both coefficients are significant. The correlation, valid for both directions of transfer with either phase dispersed, is useful for the extrapolation of performance from system to system in a given piece of equipment. Also, together with correlations for transfer area and effective driving force, it is part of the information needed for design. Chapters deal with thermodynamics of irreversible processes, development of correlations based on dimensional analysis (from Buckingham's Pi-theorem), tabulation of experimental results of previous investigators, effect of additives on extraction rates.

The large list of references is especially valuable.

K. J. De Juhasz, Germany

2347. Mason, E. A., Higher approximations for the transport properties of binary gas mixtures, *J. chem. Phys.* **27,** 1, 75–84, July 1957.

Ordinary and thermal diffusion coefficients of gas mixtures are sensitive to interaction potentials of unlike molecules. Thermal conductivity and viscosity are not. This sensitivity of diffusion coefficients requires consideration of higher-order terms in the theoretical formulations of kinetic theory. Methods of Kihara and Chapman and Cowling are extended and outlines are given showing the explicit form of second-oder approximations and the general approach for higher-order terms. N. A. Hall, USA

2348. Curtiss, C. F., Hirschfelder, J. O., and Bird, R. B., Theories of gas transport properties, Univ. Wisc. Nav. Res. Lab. (8), CF-2659, 19 pp. + 37 ref., July 1957.

Authors discuss the Lennard-Jones (6–12) potential and modifications required at high temperature and high density. Equations for coefficients of self-diffusion, viscosity, and thermal conductivity are given for pure gases and gas mixtures at low densities. Enskog theory of the transport properties of dense gases is briefly outlined, and several more recent methods are mentioned. Correlation of transport properties through use of the corresponding states principle is considered. J. A. Beattie, USA

2349. Chambre, P. L., On chemical surface reactions in hydrodynamic flows, *Appl. sci. Res.* (*A*) **6,** 2/3, 97–113, 1956.

A general basis for the formulation of flow problems involving chemical reactions on solid surfaces is laid. The analysis allows one to trace a reaction history of arbitrary complexity in a general class of boundary-layer-type flow fields which cover both external as well as internal flows under isothermal and nonisothermal conditions. From author's summary

2350. MacDonald, J. R., New integrating circuit and electrical analog for transient diffusion and flow, *Rev. sci. Instrum.* **28,** 11, 924–926, Nov. 1957.

A circuit for the electrical simulation of transient diffusion and flow of material between two volumes is described. It allows such processes to be simulated even when forward and reverse transfer rates between the two volumes are unequal. When the reverse rate is zero, the circuit functions as a very-high-input-impedance integrator of wide dynamic range and high accuracy. The circuit will integrate the current through a given resistor, even when this resistor is time varying or nonlinear. For voltage integration, it can have a minimum input impedance approaching 10^9 ohms. From author's summary

2351. Priem, R. J., Propellant vaporization as a criterion for rocket-engine design; calculations using various log-probability distributions of heptane drops, *NACA TN* 4098, 10 pp. + 1 table + 10 figs., Oct. 1957.

Vaporization rates of *n*-heptane sprays in a rocket combustion chamber were computed for various log-probability distributions and mass-median drop sizes of the spray and for an engine operating with various injection velocities, final gas velocities, initial fuel temperatures, and chamber pressures. Incomplete vaporization of a small number of large drops may be responsible for the loss in engine performance. Experimental engine performance agrees with the calculations for a spray having a geometric standard deviation of 2.5 and mass-median drop radii of 70 to 280 microns, depending on the type of injector. The calculations of the percentage of fuel vaporized are correlated with an effective chamber length. From author's summary

2352. Brunk, W. E., Experimental investigation of transpiration cooling for a turbulent boundary layer in subsonic flow using air as a coolant, *NACA TN* 4091, 14 pp. + 13 figs., Oct. 1957.

Tests were run for both constant coolant-flow rate and constant wall temperature along a flat porous plate. The results, which indicate a definite decrease in wall temperature along the plate with increase in coolant flow, are in qualitative agreement with a theory for transpiration cooling with a turbulent boundary layer.

From author's summary

2353. Comtois, W. H., The effect of flow distribution on heat-exchanger performance, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-112, 8 pp.

The condensor problem (zero capacity rate and thermal resistance ratio) is solved analytically for two-dimensional flow in which fluid velocity V varies with cross-channel distance X. Heat-transfer coefficient is assumed to vary as a power function of the fluid velocity. The effect of maldistribution of flow on performance of a counterflow heat exchanger is estimated by a simple two-lump approximation. Interesting qualitative conclusions are presented. J. L. Mason, USA

2354. Short, B. E., and Treat, B. F., Effects of tube bundle-to-shell clearance on pressure drop and heat transfer in shell-and-tube heat exchangers, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-49, 15 pp.

Results reported in this paper represent a study of the effect on heat transfer and pressure drop of the clearance between the tubes and exchanger shell for a small shell-and-tube heat exchanger. These results are primarily for the laminar flow region, although some are presented from the data for the transition and turbulent regions. The pressure-drop data are presented principally on the basis of the friction factor for flow across the tube bank. The by-pass channel friction factor for one of the tube bundles is shown as a function of the Reynolds number for this channel to indicate the region of departure of the by-pass stream from laminar flow. The heat-transfer results are shown, for several tube bundles and several tube-bundle-to-shell clearances, in terms of the Colburn j-factor (except for the viscosity ratio) as a function of Reynolds

number based on tube diameter, average maximum velocity of cross flow, and viscosity at average temperature; and also based on an equivalent diameter for flow across the tube bundle, average maximum velocity allowing for the by-pass stream, and average of viscosities at terminal temperatures.

From authors' summary

2355. Brouillette, E. C., Mifflin, T. R., and Myers, J. E., Heat-transfer and pressure-drop characteristics of internal finned tubes, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-47, 9 pp.

It was the purpose of this investigation to determine the effect of a type of internal fin on the heat-transmission and pressure-drop characteristics of copper tubing. The fins were produced by cutting 60-deg, V-shaped notches on the inner surface of five specimens of tubing. The number of notches or fins varied from 8 to 32 per in. of length, and the ratio of fin height to tube diameter ranged from 0.009 to 0.050. The measured values of heat-transfer coefficients for the finned tubes were from 10 to 100% greater than coefficients measured on a plain tube. Friction factors were also greater for the finned tubes by amounts ranging from 15 to 400%. The results indicate that fin height has a greater effect in increasing the heat-transfer coefficient than the number of fins.

From authors' summary

2356. Hausenblas, H., Behavior of gas turbine heat exchangers at low loads (in German), *Motortech. Z.* **18,** 9, 288–290, Sept. 1957.

2357. Kichigin, M. A., Researches on heat exchange, hydraulic resistance and optimum working conditions in heat-treating installations (in Russian), *Izv. Kievsk. politekhn. in-ta* no. 15, 172–180, 1954; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7569.

A brief survey of the work of the Chair of Theoretical and General Heat Engineering.

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2358. Shlyakhto, P. N., and Guttkin, L. V., An aerodynamic analysis of electric traction motors (in Russian), *Vestn. elektroprom-sti* no. 3, 17–22, 1954; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8214.

A methodology is proposed for the analysis and calculation of the air-cooling system of electric traction motors.

Formulas are presented for the experimental determination of the coefficients of resistance of the sections of a ventilating system of an electric motor, enabling the percentage distributions of the air flow in the armature passages, between the pole windings and in the annular gap between the armature and the poles, to be calculated.

M. L. Lidov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2359. Eckman, D. P., and Lefkowitz, I., Optimizing control of a batch chemical process, *Control Engng.* **4,** 9, 197–204, Sept. 1957.

2360. Backstrom, M., The use of capillary tube as an expansion device (in Swedish), *Kyltekn. Tidskr.* no. 5, 213–218, Oct. 1957.

2361. Benedict, R. P., Review of practical thermometry, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-203, 25 pp.

A brief resume of the steps leading to a satisfying concept of temperature from a thermodynamic viewpoint is first given. The International Temperature Scale is reviewed. Thermal response and thermal recovery are defined. Several practical means for realizing temperatures are indicated in some detail. Finally, the uncertainty associated with a temperature measurement is considered.

From author's summary

Combustion

(See Revs. 2190, 2214, 2236)

Acoustics

(See also Rev. 2169)

2362. Carome, E. F., Gutowski, F. A., and Scheule, D. E., Basic concepts of ultrasonic interferometry in liquids, *Amer. J. Phys.* **25,** 8, 556–564, Nov. 1957.

The well-known interaction of electric and acoustic impedances in an electric circuit including a piezo quartz is studied for the determination of the sound absorption coefficient of liquids. Starting out from the differential equation of a plane wave, the solution for a wave reflected from the free surface of a liquid in which the quartz crystal is submerged is derived for the case of no sound absorption. Showing the aggravation of the problem with sound absorption, a simplified equation is applied for the determination of the acoustic impedance. Tests are conducted in which the acoustic impedance is determined electrically. When the liquid column length is changed the impedance periodically changes from minimum to maximum values. A suitable function of the acoustic impedance is determined that follows a straight line when plotted against the liquid column length. The slope of this line is equal to the absorption coefficient. Though the general method described is not new, paper is a good introduction into acoustic interferometry and is recommended to workers in this field.

H. J. Ramm, USA

2363. Tait, R. I., An apparatus for the study of ultrasonic propagation in liquids under pressure (in French), *Acustica* **7,** 4, 193–200, 1957.

A description is given of an apparatus designed for the measurement of velocity and absorption of ultrasonics in liquids. The apparatus has a capacity of two litres and can cover the range 0 to 703 kg/cm^2 (0 to 10,000 lb/sq. in.). A pulse method is used for both velocity and attenuation and either fixed or variable path-length can be used.

Measurements in water at temperatures 15 C to 80 C are presented and compared with recent measurements by others and with theory.

From author's summary

2364. Greenspan, M., and Tschiegg, C. E., Speed of sound in water by a direct method, *J. Res. nat. Bur. Stands.* **59,** 4, 249–254, Oct. 1957.

The speed of sound in distilled water was measured over the temperature range 0 to 100 C with an accuracy of 1 part in 30,000. The results are given as a fifth-degree polynomial and in tables. The water was contained in a cylindrical tank of fixed length, terminated at each end by a plane transducer, and the end-to-end time of flight of a pulse of sound was determined from a measurement of the pulse-repetition frequency required to set the successive echoes into time coincidence.

From authors' summary

2365. Resler, E. L., Jr., Characteristics and sound speed in nonisentropic gas flows with nonequilibrium thermodynamic states, *J. aero. Sci.* **24,** 11, 785–790, Nov. 1957.

A theory is developed extending the method of characteristics to flow problems involving lagging heat capacities and/or finite chemical reaction rates. Special cases appropriate to present high-speed flow problems are considered in more detail; namely, heat-capacity lag and dissociation of a gas made up of diatomic molecules. The theory is easily adaptable to the usual finite-wave approximation used for computations.

From author's summary by P. R. Owen, England

2366. van Itterbeek, A., de Rop, W., and Forrez, G., Measurements on the velocity of sound in nitrogen under high pressure, *Appl. sci. Res. (A)* **6,** 5/6, 421–432, 1957.

Using an acoustical interferometer for high pressures authors measure the velocity of sound in nitrogen gas between 1 and 75 atm as a function of pressure and at different temperatures. The experimental data are compared with the direct measurements on the equation of state of nitrogen gas.

From the experimental results on the velocity, they calculate the change of the ratio of the specific heats and the specific heats themselves as a function of pressure, also at different temperatures. From authors' summary

2367. Lassiter, L. W., and Hess, R. W., Calculated and measured stresses in simple panels subject to intense random acoustic loading including the near noise field of a turbojet engine, *NACA TN* 4076, 16 pp. + 15 figs., Sept. 1957.

Flat 2024-T3 aluminum panels measuring 11 by 13 inches were tested in the near noise fields of a 4-in. airjet and turbojet engine. The stresses which were developed in the panels are compared with those calculated by generalized harmonic analysis The calculated and measured stresses were found to be in good agreement.

In order to make the stress calculations, supplementary data relating to the transfer characteristics, damping, and static response of flat and curved panels under periodic loading are necessary and were determined experimentally. In addition, an appendix containing detailed data on the near pressure field of the turbojet engine is included. From authors' summary

2368. Wolfe, M. O. W., The structural aspects of jet noise, *J. roy. aero. Soc.* **61,** 554, 103–106, Feb. 1957.

The noise pressures generated by the jet streams from high-thrust jet engines are capable of exciting potentially dangerous fatigue stresses in aircraft structures. Author describes experimental work being done at RAE and gives some results. Work included development of a high-level noise microphone. Results show a wide range of frequencies for the generated noise and absence of marked peaks in the spectrum. Greatest pressures are about 13 psf or 150 db and occur at 200–700 cps. It is concluded that aircraft structures cannot be detuned to avoid resonance since excitation spectra are continuous. The best solution appears to be to stiffen the structure on broad strength considerations and to introduce damping wherever possible. Honeycomb construction accomplishes both.

The work described is a valuable contribution which quantizes certain aspects of the jet noise problem. Much remains to be done before the response of structures to random noise excitations is fully understood. E. L. Foster, USA

2369. Franklin, R. E., The excitation of structural vibrations by noise, *J. roy. aero. Soc.* **61,** 554, 106–108, Feb. 1957.

Author considers problem of transmission of sound through walls to clarify mechanisms involved. The excitation of structural vibrations by noise is said to be part of the same general problem, but with attention focused on a different aspect, namely the amplitude of vibration of a panel and the resulting stresses induced in the panel and its supports. The factors which influence sound transmission also influence amplitudes of vibration. Author discusses two conditions, resonance and coincidence, for either of which panel becomes almost transparent to sound.

By considering a generalized force acting on a panel, author concludes that panel acts as a frequency filter and a wave number filter as well. Power is found to be transmitted only when the pressures are in phase over the surface of the panel, i.e., when the space-correlation coefficient is unity. When space-correlation coefficient is nearly unity, panel will vibrate mainly in its first mode, for which simple calculations will give a good estimate of panel amplitude.

Paper should help to clarify some of the aspects of excitation of structural vibration for engineers who need a qualitative understanding of the problem. E. L. Foster, USA

2370. Hetzel, K. W., Experimental study of the effects of jet noise on an aircraft structure, *J. roy. aero. Soc.* **61,** 554, 112–114, Feb. 1957.

Author reports on a noise investigation program designed to provide design data during development of the Vicker Supermarine Type 544 aircraft. Tests were run subjecting a full-scale rear fuselage section to the efflux from a Rolls-Royce Avon engine.

Damage usually began at countersunk skin attachments: Subsitituting mushroom head for countersunk rivets and/or increasing the local material thickness and cut-countersinking overcame the troubles. Internal stiffeners also developed cracks at discontinuities and changes of section. There was some evidence of severe fretting of some joints where rivets had loosened.

The test program has indicated certain broad lines on which structures could be developed to withstand jet noise: (1) Panels may be supported around their edges only to avoid rivet holes within the panel boundary and eliminate concentrated masses which create inertia loads. (2) Noise damage is a fatigue phenomenon and structures must be designed to avoid discontinuities and stress concentration elements. (3) Sandwich panels are less subject to failure than stringer panels.

E. L. Foster, USA

2371. Simmons, J. C., Summary of the discussion, *J. roy. aero. Soc.* **61,** 554, 114–115, Feb. 1957.

Author gives some of the comments which came out during discussion periods at the symposium. The difficulty of relating low-level fatigue test results to the endurance of a component subjected to tensile loading is mentioned. The designer needs a working theory which will give the fatigue life, taking into account the significant variables. Even with this, however, the stress distribution in a structure caused by jet noise is complicated by the large number of natural modes, the effects of stress concentration, etc. A simple theoretical or empirical approach would be useful in many cases.

In choosing a material, it is necessary to consider the fatigue characteristics, internal damping, and sometimes thermal properties as well.

Stiffening produces higher modes and increased damping, thereby lowering the induced stresses. A disadvantage of riveted stiffeners was that failure could occur at riveted connections. Riveted joints are believed to produce a large proportion of the damping in many structures.

Honeycomb panel construction has several advantages: (1) virtually eliminates panel vibration, (2) absence of riveted connections, and (3) good damping properties.

Reduction in jet noise in the future is incompatible with demands for increased thrust and lowered fuel consumption.

Since jet noise damage is greatest when the relative jet velocity (to air) is greatest, some improvement might be obtained by not bringing the engines to full throttle during takeoff until the forward velocity of the aircraft has increased to a reasonable value. This method has been employed on at least one aircraft.

E. L. Foster, USA

2372. Campbell, A. J., Investigation of wide angle diffuser with air augmentation for use as a jet muffler, *Univ. Toronto Inst. Aerophys. UTIA Rep.* 15, 11 pp. + 9 figs., Aug. 1957.

A wide-angle diffuser for reduction of the noise of a jet, by taking advantage of the AV law, was combined with a short-length augmentation system, which, on a full scale muffler, would provide cooling air flow to the diffuser. A large reduction in velocity and

a small cooling air flow were attained when screens were used to prevent separation of flow in the diffuser. The experimental results, when compared with current literature, indicate that grids of rods or pipes (which could be cooled internally) would also provide satisfactory resistance. However, the experiments (which may not be representative) indicate a pronounced noise augmentation when rods were used. A theory is developed which predicts qualitatively the induced air flow when a short mixing length is used. In the frequency bands which are of interest, the noise level of the model was higher than that of the free jet. However, the main noise source was found to be inside the muffler. It appears to be possible to reduce its output by aerodynamic means, and further to decrease the radiated sound by acoustic treatment.

From author's summary

2373. Fuchs, H., Investigations of ground resonance in helicopters with an analogue computer, *J. Helicop. Assn.* **11,** 5, 263–290, Oct. 1957.

2374. Makeev, A. N., Calculation of exhaust systems of two-stroke marine engines with crank-chamber scavenging (in Russian), *Ryb. Kb-vo.* no. 2, 55–57, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6547.

In the solution of the problem of determining the most favorable dimensions of the exhaust pipeline, author examines gases in the silencer as an air spring, and gases contained in the exhaust pipe as a mass capable of effecting compression and extension of this spring during the oscillating motion of the gas. In this statement of the problem, in author's opinion, the compression energy of the gas in the pipe and silencer and the kinetic energy of the motion of the gases in the pipe are taken into account.

A formula is given for determining the period of oscillation of the gas pressure in the exhaust system and another for determining the most suitable length of the exhaust pipe.

If the engine in operation works at variable rpm, the best length of pipe, in author's opinion, should be determined according to the nominal rpm. It is pointed out that a test check of the best length of pipe in the laboratory confirmed the satisfactory correspondence of the theoretical with the practical data.

When the most suitable exhaust pipe turns out to be short and the conditions of assembly make it impracticable, author suggests inserting a second additional silencer into the pipe. The capacity of this silencer should be approximately 10 times greater than that of the first silencer.

M. G. Kruglov

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

Ballistics, Detonics (Explosions)

(See Revs. 1887, 1986, 2351)

Soil Mechanics, Seepage

(See Revs. 1991, 2050, 2115, 2139, 2155, 2377, 2381, 2384)

Micromeritics

(See also Rev. 2191)

2375. Happel, J., Viscosity of suspensions of uniform spheres, *J. appl. Phys.* **28,** 11, 1288–1292, Nov. 1957.

Author derives a theoretical relationship between the relative viscosity and volume concentration of suspensions of uniform spheres. This theoretical prediction is in good agreement with published experimental data for concentrations up to 40%. Deviations observed for higher concentrations are attributed to friction between suspended particles as the loose packed condition is approached. For very low concentrations the relationship reduces to the same form as the Einstein equation but differs by a numerical factor. Author suggests that this difference depends upon the method of approach to a dilute solution. The present theory assumes that near the limit of zero concentration there is still a large number of very small particles and that the dominant factor is the interaction between suspended particles. The Einstein theory considers particle-wall interaction as dominant. The success of the physical model proposed by the author suggests that the model could be used for more detailed studies, e.g., including inertial effects or assuming nonspherical particles.

G. C. Wallick, USA

2376. Batel, W., Error sources in the determination of grain-size distribution (in German), *Chem.-Ing.-Tech.* **28,** 2, 81–87, 1956.

The determination of grain structure of an agglomerate requires operations such as sample taking, sample distribution, grain-size analysis, graphic representation, and evaluation of results. In these operations events can occur, such as mixture separation, agglomeration of grains, etc., whereby the measured grain structure may substantially differ from the actual structure. The error sources of each of these influences are investigated in detail and measures are indicated for their mitigation. Factors such as duration of sieving, type of grain, mesh width and uniformity, stroke and speed of the sieve machine, capillary and electrostatic agglomeration of particles are analyzed, qualitatively and mathematically. Error sources of the graphic representation, in particular interpolation and extrapolation, are analyzed. While this investigation deals specifically with dry goods, its methods and findings are applicable also to the evaluation of spray droplet-size distributions.

K. J. De Juhasz, Germany

2377. Owens, W. W., Parrish, D. R., and Lamoreaux, W. E., An evaluation of a gas drive method for determining relative permeability relationships, *J. Petr. Technol.* **8,** 12, 275–280, Dec. 1956.

The complexity of methods for determining the gas-oil flow characteristics of reservoir rock samples leaves much to be desired. This investigation deals with the development of a simplified unsteady-state (gas drive) laboratory method for measuring relative permeability relationships of small core samples. A procedure for selecting unifrom rock samples was also developed. Factors known to influence this type test, such as oil viscosity, gas expansion, and pressure differential, were evaluated. The method of calculating the test results gives valid data over a wide range of gas expansion. The limits of pressure differential and oil viscosity which would insure reliable results are defined. In comparison with other presently used testing methods, the gas drive method requires considerably less apparatus, is less time consuming, and is more readily adaptable to a routine type core test.

From authors' summary by M. L. Baker, USA

2378. Salekhov, G. S., Method of solving the problem of control of the motion of a petroleum-bearing contour in beds having water-pressure conditions (in Russian), *Izv. Kazansk. fil. Akad. Nauk SSSR., Ser. fiz.-matem. i tekhn. nauk* no. 8, 16–29, 1955; *Ref. Zh. Mekh.* no. 10, 1956, Rev. 6757.

For a solution of the problem studied earlier by the author [title source **5,** 3–15, 1954], use is made of minimum quadratic error with an assumed norm. The corresponding expression of quadratic error varies as a result of the outputs of the operational and pressure crevices. The position of the crevices is fixed. The bed liquid is everywhere homogeneous; "the petroleum-bearing contour", the boundary separating the water and the petroleum, is

represented by the line of the particles recorded. The law of displacement of this line should, in the problem in question, give a minimum deviation in the sense of a mean quadratic error from the given law of displacement of the petroleum-bearing contour.

For solution of the problem an expression was set up for the mean quadratic error of the boundary condition, which should be satisfied by the pressure gradient of the mobile boundary of demarcation of the liquids. In this, use is made of the pressure distribution which is known for the case of a homogeneous flow. As a result of the variation of the quadratic functional error, a linear system of equations is obtained, from which the only possible distribution of the output in the system of crevices is obtained, if the position of the latter is fixed.

A minimum of the mean quadratic error in the deviation of the petroleum-bearing contour from the given movement corresponds to the found distribution of the yield. The method suggested for solving the problem of control of the displacement of the petroleum-bearing contour makes it possible to find the best approximation to the given law of motion of the contour. But this method does not guarantee against the possibility of formation of considerable local disturbances of the petroleum-bearing contour. The method is illustrated by examples.

V. P. Pilatovskii

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2379. Klimentov, P. P., Determination of the coefficient of filtration for a given evacuation from a solid aperature to the extent of one degree of determination of the level (in Russian), *Razvedka i okhrana medr.* no. 3, 45–48, 1955; *Ref. Zh. Mekh.* no. 12, 1956, Rev. 8402.

A graphical solution of the Dupuis equation is put forward for the yield of the ideal wall Q jointly with the empirical equation of I. P. Kusakin for the radius of influence of such a wall when motion is steady. In the result the author determines, for the given rate of pumping out, the coefficient of filtration k and the radius of influence. Kusakin in 1931–34 similarly made use of these equations. It has to be pointed out that nowadays in the determination of Q or k, conditioned by steady motion in place of the radius of influence, the radius of contour of delivery or discharge of the water-bearing layer is introduced. N. N. Verigin

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2380. Diprima, R. C., On the diffusion of tides into permeable rock of finite depth, *Quart. appl. Math.* **15,** 4, 329–330, Jan. 1958.

Mathematical analysis is made of flow in a porous stratum, one end of which is open to an ocean subjected to tides. The case of infinite depth of medium is reviewed, and equations for case of finite depth developed. Numerical computations are carried out for several values of the dimensionless depth. The limiting case of shallow water theory is also studied. From graphs in the paper it is possible to predict the amplitude and phase lag of the free-surface oscillation as a function of the dimensionless distance inland.

Solution is clearly developed and all assumptions required to reduce the physical problem to one readily solved are explained. Use of the Darcy law as one of equations of motion results in an equation of diffusion type rather than a wave equation. Hence the amplitude decreases with distance inland.

Reviewer believes paper will be of particular interest to irrigation engineers because it provides a means of estimating the characteristics of the flow medium from observations of well fluctuations. Furthermore, attention is paid to values of the dimensionless constants encountered in practice.

W. D. Baines, Canada

2381. Aronofsky, J. S., and Heller, J. P., A diffusion model to explain mixing of flowing miscible fluids in porous media, *J. Petr. Technol.* **9,** 12, 345–349, Dec. 1957.

Paper presents a mathematical analysis of the fluid mixing which occurs during flow through porous media. The analysis is based on the well-known diffusion equation with mass transfer term. It is pointed out that the use of this equation is justified by a single general assumption which does not specify any particular mechanism for the mixing process. Formulas are given for tracer fluid concentrations for two different boundary and initial conditions. Calculated numerical values compare closely with some published results of experiments in which no viscosity or density difference existed between displaced and displacing fluids.

From authors' summary

2382. Preissmann, A., Concerning seepage below canals (in French), *Houille blanche* **12,** 2, 181–188, Mar./Apr. 1957.

The introduction defines the flow conditions below a canal and describes various means of utilizing the hodograph, pointing out their disadvantages.

Author proposes and describes a general method of arriving at the flow network with reasonable accuracy, without involved calculations. Applications of the method are: the case of a canal of symmetrical, triangular section; the case of canals of rectangular or trapezoidal form.

Extension of the method is given to the case where the very permeable layer is not deep lying.

Isoperimetrical problem discussed: determination of the section form giving the minimum seepage for a given section area.

From author's summary

2383. Newland, P. L., and Allely, B. H., Volume changes in drained triaxial tests on granular materials, *Géotechnique, Lond.* **7,** 1, 17–34, Mar. 1957.

Starting from the basis that the direction of sliding of one particle relative to another is, in general, inclined at an angle to the direction of the applied shear stress, a theory is developed to account for the difference between peak and residual stresses in terms of the volume expansion of the mass during shear. A reason is given to explain why the theory based on energy considerations cannot fully account for this difference.

It is also suggested that the observed differences between the angle of sliding friction $\phi_\mu (= \tan^{-1}\mu)$ and the angle of internal friction ϕ_f are explainable in terms of the mode of failure which is itself a function of ϕ_μ. The analysis is extended to cover both direct and triaxial shear tests.

Experimental results obtained from triaxial tests on samples of lead shot are presented and the proposed theory appears to fit these results, after several modifications have been made to them, better than the theory based on energy considerations.

Tests on a set of samples lubricated with graphite are a novel feature of the experimental program, and the results from these tests coupled with the results obtained from sliding friction tests are shown to be in general agreement with the proposed theory.

From authors' summary

2384. Chapman, T. G., Two-dimensional ground-water flow through a bank with vertical faces, *Géotechnique, Lond.* **7,** 1, 35–40, Mar. 1957.

Paper deals with Muskat's analytical solution of the problem of ground-water flow through a bank with vertical faces. Sufficient numerical calculations have been made to enable the height of the seepage surface to be determined for any geometry of the system. The results are compared with previously published solutions, and this leads to an examination of the critical depth theory. It is shown that the shape of the free surface can be expressed with considerable accuracy by a simple formula.

From author's summary

Geophysics, Meteorology, Oceanography

(See Rev. 2245)

Lubrication; Bearings; Wear

(See also Revs. 1946, 1985, 2034)

2385. Barwell, F. T., The Sommerfeld variable, its origin and further generalization, Mech. Engng. Research Lab. L. D. R. 29/56, East Kilbride, Glasgow, Scotland, 11 pp. + 2 figs., Aug. 1956.

Author concerns himself with the writing of the Sommerfeld parameter for hydrodynamic lubrication of journal bearings in a form most useful for the practical engineer. He pleads for $P/\eta\ U \cdot \Psi^2$ (P = load per unit width, η = viscosity, U = velocity—linear or peripheral, Ψ = geometric factor in Sommerfeld number). Reference is made to experiments which show that a load of 400 lb may be carried without damage between cylinders 2 in. in diameter, one of which is moved at a peripheral speed of 60 fpm when lubricated with a material of viscosity of 200 cp.

R. Schnurmann, England

2386. Milne, A. A., An alternative approach to the theory of hydrodynamic lubrication, Mech. Engng. Research Lab. L. D. R. 19/56, E. Kilbride, Glasgow, Scotland, 6 pp. + 2 figs., July 1956.

Discussion of hydrodynamic equations for a tilted pad bearing when the solution does not depend on Reynolds' assumption of negligible convergence of flow. For larger angles of inclination, direct application of Reynolds' assumptions would give an underestimate of the forces acting on the pad. With the slight modification of the pressure being assumed to be constant along an arc instead of across the film of lubricant, the calculated load capacity is slightly greater than that given by the exact analysis. The error increases with the inclination, but even at an angle of 30° the discrepancy between the calculated normal loads is less than 1%. When the angle of inclination is not small, consideration must be given to the lubricant flow at the inlet and outlet of the bearing.

R. Schnurmann, England

2387. Kochanowsky, W., Application of the Reynolds theory for lubricant friction for the calculation of oil consumption in cylindrical plain bearings (in German), *ZAMM* **36,** 5/6, 212–221, May/June 1956.

The main previous theories allowing the computation of the quantity of oil flowing out of the ends of a cylindrical bearing, and based on integration of Reynolds well-known equation, are first reviewed: I—Vogelpohl's and Bauer's theories, following approximate variational procedures, as in previous Schiebel's theory; II—Sassenfeld's and Walther's theory, based on a numerical finite-differences method of integration; III—Gümbel's and Fränkel's too-simplified theories, computing oil flow on the basis of results valuable for plain bearings.

For bearings embracing an angle of 180°, oil transverse flow computed by such theories is plotted in dimensionless terms versus relative eccentricity.

Afterwards, author develops a new involved calculation, following a paper by H. Reissner, starting from the original Navier-Stokes equations without employing the generally admitted simplifications leading to Reynolds equation.

But following Reissner's procedure, which refers to a 360° bearing, to avoid excessive complications, author still assumes pressure to be zero in both minimum and maximum thickness sections (what looks rather unjustified since, in a 180° bearing, maximum thickness section is out of the embraced arc).

Numerical results obtained show good agreement with previous theories (except with Gümbel's and Fränkel's very rough theories), which, author says, should confirm the validity of Reynolds' simplifications also in this case.

Reviewer does not deny this validity, being in doubt, on the contrary, that Reynolds' equation should need a particular confirmation to compute oil flow, but, owing to the assumed boundary conditions, he thinks that the present paper cannot claim to have given such a confirmation. R. Giovannozzi, Italy

2388. Sasaki, T., and Mori, H., Fluid lubrication theory of multiple-film journal bearings, Proc. Sixth Japan nat. Congr. appl. Mech., Univ. of Kyoto, Japan, Oct. 1956, 319–322.

Authors analyze two examples of multiple-film journal bearings, each bearing being composed of four pressure-generating surfaces each with an oil inlet groove. Viscosity is assumed constant and end leakage is neglected. Load capacities of each example are computed at selected eccentricity ratios and shown in curve form. Locus of the journal center is shown for two angles of load application and compared to the full journal locus. Frictional moments are compared to Petroff's formula.

Authors conclude that multiple-film bearings have less frictional resistance and better oil-cooling characteristics than regular journal bearings.

Reviewer finds the text confusing and in need of editing due to the misuse of English grammer. D. F. Hays, USA

2389. Lukin, G. Ta., The calculation of plain thrust bearings (in Russian), Trans. Leningr. Sec. All-Soviet Scient-Eng. Techn. Soc. Water Transport no. 2, 51–71, 1955; *Ref. Zh. Mekh.* no. 11, 1956, Rev. 7531.

The two-dimensional problem is solved of the oil (lubricant) wedge in one element of a thrust bearing on the basis of the Reynolds equation for the pressure. A variation of the viscosity with temperature is suggested, associated with the work of friction and the volume of flow.

The method of solution represents a combination of the method of successive approximations and the grid method. A specimen calculation is appended. V. Ya. Natanzon

Courtesy Referativnyi Zhurnal, USSR
Translation, courtesy Ministry of Supply, England

2390. Roudebush, W. H., An analysis of the effect of several parameters on the stability of an air-lubricated hydrostatic thrust bearing, *NACA TN* 4095, Oct. 1957.

Paper analyzes, in order to examine the effects of certain bearing factors upon the stability of a gas-lubricated hydrostatic thrust bearing, a simplified differential equation of motion in an equilibrium. Equation is established under an assumption that the bearing is constructed by two standstill disks of infinite diameter gapped by air flowing radially from the center hole of a disk.

An unstable bearing having a diameter of twelve inches was taken as a standard example, and the behaviors of bearing factors to stabilize this bearing were studied.

Conclusion shows that bearing is stabilized by decreasing the pad volume or by increasing the orifice area to decrease bearing rigidity. While both the decrease of pad radius and the increase of orifice area, decrease the bearing capacity, an appropriate design for an applied load is needed. The magnitude, variation and fluctuating time of an applied load do not influence so seriously the stability of the bearing, so that the design of a stable bearing of above dimension supporting a large load such as 15,000 lb may be possible. Moreover, if the bearing is heated, the weight flow for a certain load decreases to stabilize the bearing. Therefore the design of such bearing becomes easy when the bearing is for high-temperature use. H. Mii, Japan

2391. Richardson, H. H., Static and dynamic characteristics of compensated gas bearings, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-138, 7 pp.

In compensated gas bearings a fluid film is maintained by an externally pressurised gas supplied through restrictors in such a way that pressures in the film increase in regions where the bearing clearance decreases under load. In a theoretical study author shows that a "pool-type" bearing, in which there are external fixed supply restrictors, may be dynamically unstable if the "pool" volume is large in comparison with the film volume. It is shown that an inherently compensated bearing, in which the inlet restrictor is effectively the inlet contraction to the fluid film, will not be unstable. A sample numerical design study is made.

G. D. S. MacLellan, England

2392. Tao, L. N., A theory of lubrication in short journal bearings with turbulent flow, ASME Ann. Meet., New York, N. Y., Dec. 1957. Pap. 57-A-68, 5 pp.

Using the Ocvirk approximation for short bearings and a general power law for the velocity distribution (Blasius one-seventh power law and laminar parabolic distribution being special cases), author derives theoretical relation between load carried and shaft attitude (eccentricity/clearance), with Reynolds number as an additional parameter. It is assumed that pressure is zero in the divergent part of the film and (without discussion by author) that the turbulent velocity profile is fully developed from the start of convergence. The analysis shows that turbulence decreases the attitude for a specified value of the Sommerfeld number, the effect increasing with Reynolds number.

G. D. S. MacLellan, England

2393. Ausman, J. S., and Wildmann, M., How to design hydrodynamic gas bearings, *Prod. Engng.* **28,** 21, 103-106, Nov. 1957.

2394. Moore, C. C., and Lewis, P., Current development problems in high temperature aircraft roller bearings, ASLE-ASME Lubrication Conf., Toronto, Ontario, Canada, Oct. 1957. Pap. 57-LUB-4, 8 pp.

2395. Bisson, E. E., Johnson, R. L., and Anderson, W. J., On friction and lubrication at temperatures to 1000° F with particular reference to graphite, ASLE-ASME Lubrication Conf., Toronto, Ontario, Canada, Oct. 1957. Pap. 57-LUB-1, 13 pp.

2396. Wilcock, D. F., Predicting performance of starved bearings, *Lubrication Engng.* **13,** 6, 348-352, June 1957.

Paper outlines procedure for determining extent of oil film, eccentricity ratio, power loss, and operating temperature of starved bearings. Oil feed to bearings fed by wicks or oil-rings must be determined empirically by experiment. Procedure for determining time to failure after oil supply cutoff is also given.

W. J. Anderson, USA

Marine Engineering Problems

(See Revs. 1897, 2244)

Letter to the Editor

2397. Concerning AMR 11, Rev. 110 (January 1958) Klein, B., Buckling of simply-supported rhombic plates under externally applied shear, *J. roy. aero. Soc.* **61,** 557, 357-358, May 1957.

In agreement with a communication from the author, if the symbol b in formula (4c) for the critical q_{cr} be taken as the semi-diagonal shown in Fig. 1 of the paper, there is then agreement with the result given for a square plate in Timoshenko's book on elastic stability.

W. H. Hoppmann, II

Books Received for Review

ABRAMSON, H. N., An introduction to the dynamics of airplanes, New York, Ronald Press, 1958, viii + 225 pp. $4.50.

CAMBEL, A. B., and JENNINGS, B. H., Gas dynamics, New York, McGraw-Hill, 1958, xiii + 415 pp. $11.00.

COBINE, J. D., Gaseous conductors; theory and engineering applications, New York, Dover Publications, xix + 606 pp. $2.75. (Paperbound)

CONSIDINE, D. M., edited by, Process instruments and controls handbook, New York, McGraw-Hill, 1957, xxiii + 1383 pp. $19.50.

CONWAY, H. G., Landing gear design, New York, Macmillan, 1958, viii + 342 pp. $12.00.

COUFFIGNAL, L., Manuels de calculs techniques. Vol. II: Resolution numerique des systems d'equations lineaires, Paris, Gauthier-Villars, 1956, iii + 180 pp. (Paperbound)

DRYDEN, H. L., VON KARMAN, T., and KUERTI, G., Advances in applied mechanics, Vol. 5, New York, Academic Press Inc., 1958, x + 459 pp. $12.00.

EWING, M. W., JARDETZKY, W. S., and PRESS, F., Elastic waves in layered media, New York, McGraw-Hill, 1957, xi + 380 pp.

FRANK, J., Nichstationare Vorgange in den Zuleitungs- und Ableitungskanalen von Wasserkraftwerken, second edition, Berlin, Springer-Verlag, 1957, xi + 333 pp.

GELEJI, A., Die Berechung der Krafte und des Arbeitsbedarfs bei der Formgebung im Bildsamen Zustande der Metalle, second edition, Budapest, Akademiai Kiado, 1955, 415 pp.

GRAY, D. E., American Institute of Physics handbook, New York, McGraw-Hill, 1957, xi + 1543 pp. $15.00.

GUDERLEY, K. G., Theorie schallnaher Stromungen, Berlin, Springer-Verlag, 1957, xv + 376 pp.

KAMKE, E., Differentialgleichungen Reeler Funktionen, Leipzig, Adademische Verlagsgesellschaft Geest & Portig K.-G., 1956, xiv + 442 pp.

KAMPS, R., Lager- und Schmiertechnik insbesondere von Verbrennungsmotoren, Dusseldorf, Kommissionsverlag: VDI-Verlag GmbH, 1957, xvi + 364 pp.

OPRECHT, U., Regeratoren fur Kleingasturbinen, Zurich, Verlag Leemann, 1957, 79 pp.

PELTIER, J., Manuels de calculs techniques, Vol. III: Resolution numerique des equations algebriques, Paris, Gauthier-Villars, 1957, iv + 244 pp. (Paperbound)

Proceedings of the Fourth Conference on Soil Mechanics and Foundation Engineering, Vol. I, London, Butterworths Scientific Publications, 1957, xiii + 466 pp. $79.50 for all three volumes.

Proceedings of the Fourth Conference on Soil Mechanics and Foundation Engineering, Vol. II, London, Butterworths Scientific Publications, 1957, xi + 467 pp. $79.50 for all three volumes.

PUGSLEY, A., The theory of suspension bridges, New York, St. Martins Press, Inc., 1957, vii + 136 pp. $10.00.

ROSTOKER, W., The metallurgy of vanadium, New York, John Wiley & Sons, 1958, ix + 185 pp. $8.50.

SMITH, O. J. M., Feedback control systems, New York, McGraw-Hill, 1958, xviii + 694 pp. $13.50.

TAYLOR, G. I., Scientific papers, Vol. I: Mechanics of solids, edited by G. K. Batchelor, New York, Cambridge University Press, 1957, x + 593 pp. $14.50.

TIPEI, N., Hidro-aerodinamica lubrificatiei, Romine, Editura Academiei Republicii Populare, 1957, 695 pp.

TRICOMI, F. G., Integral equations; pure and applied mathematics, Vol. V., New York, Interscience Publishers, 1957, viii + 238 pp. $7.00.

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Agostinelli, A. 2167
Aizerman, M. A.....1927
Alekseev, A. S.....1948
Alexander, G. L.....2198
Alexandrov, A. Ya.....2018
Allely, B. H.....2383
Amenzade, Yu. A.....2054
Amundson, N. R.....1971
Anderson, G. E.....2343
Anderson, R. A.....2117
Anderson, W. J.....2395
Arbenz, K. 1858
Aronofsky, J. S.....2381
Ashley, H. 2218
Ashwood, P. F.....2205
Ausman, J. S.....2393
Azimov, B. A.....2054
Backstrom, M. 2360
Baehr, H. D.....2025
Bagdasarov, A. D.....2085
Bakhvalov, N. S.....1855
Balekjian, G. 2337
Banerjee, K. K.....2126
Bankovskaya, N. V.....1944
Baron, T. 2346
Bartas, J. G.....2335
Bartlett, R. J.....2130
Barwell, F. T.....2385
Bashkirov, A. N.....2274
Basilevich, A. I.....2166
Batel, W. 2376
Beecher, D. T.....2309
Beedle, L. S.....2133
Behlendorf, E. 2070
Beitler, S. R.....2305
Beletskii, V. Ya.....1919
Belkina, G. L.....2054
Belotserkovskii, O. M....2206
Belousov, T. T.....1952
Benedict, R. P.....2361
Bennett, F. D.....1957
Benninghoff, J. M.....2266
Bertotti, B. 2256
Bertram, G. 1856
Bevans, J. T.....2334
Beyer, R. 1899
Beyer, R. T.....1869
Bezemer, C. 2191
Binnie, A. M.....2241
Birch, F. 1875
Bird, R. B.....2348
Bisson, E. E.....2395
Black, J. 2177
Blackburn, W. S.....2014
Blekhman, I. I.....1983
Bleviss, Z. O.....2225
Bleyle, G. A., Jr.....1872
Bodine, E. G.....2145
Bohn, L. 2169
Boksenbom, A. 1969
Bolie, V. W.....2062
Bollard, R. J. H.....2020
Borissov, E. M.....2054
Bowen, J. C.....1874
Bowman, H. A.....1886
Boydalov, A. K.....1891
Brandt, A. 2113
Breslin, J. P.....2244
Broadwell, J. E.....2233
Brouillette, E. C.....2355
Brown, G. M.....1882
Brown, W. B.....2294
Brull, M. A.....2119
Brunk, W. E.....2352
Bryant, R. A. A.....2203
Buder, E. E.....1966
Budrin, D. V.....2320
Burns, L. F.....1970
Buthod, P. 2306
Bychkov, P. G.....2049
Cahill, W. F.....2019
Campbell, A. J.....2372
Campbell, G. S.....2216
Carlson, R. L.....2145
Carlsson, B. 1918
Carome, E. F.....2362
Carter, W. J.....2056
Chambre, P. L.....2349
Chapman, T. G.....2384
Chappelear, J. E.....2242
Charters, W. W. S.....1958
Chatten, C. K.....2168
Chebotarev, V. I.....2156
Chen, S. T.....2013
Chermozh-skaya, L. N...1936
Chiarulli, R. 2336
Choudhury, P. 2089
Clare, D. 1981
Clark, S. P., Jr.....1875
Clarke, J. H.....2209
Clarkson, B. L.....1995
Cleland, W. W.....1961
Coales, J. F.....1954
Cochran, E. P., Jr.....2168
Cockshutt, E. P.....2312
Coffin, D. O.....2316
Cohen, J. S.....2107
Coleman, W. 2038
Coles, D. 2197
Combes, J. J.....2269
Comings, E. W....1885, 2275
Comtois, W. H.....2353
Cooper, R. M.....2068
Costello, C. P.....2342
Covert, E. E.....2259
Craggs, J. W.....2228
Crane, L. J.....2237
Creager, M. O.....2328
Crisp, J. D. C.....2035
Crosby, H. W.....1872
Cross, J. L.....1886
Crosse, G. W.....2205
Curtiss, C. F.....2348
Darrow, R. G.....2305
Davidsson, W. 2040
Deitchman, S. J.....2282
de Pasquale, M. J.....2269
de Rop, W.....2366
DeWitt, W. M.....2310
d'ews Thomson, T. A...2200
Diaconis, N. S.....2325
Diaz, J. B.....1854
Dini, D. 2235
Dillaway, R. B.....2229
Diprima, R. C.....2380
Dmi'triev, B. S.....2060
Dobronravov, V. V.....1902
Dorn, W. S.....2131
Dornbusch, P. E.....1967
Dowman, R. D.....2129
Doyle, D. V.....2136
Drake, D. G.....2234
Dressler, R. F.....2336
Driscoll, G. C., Jr.....2133
Drucker, D. C....2124, 2125
Drummond, W. E.....2201
Dudnikov, E. G...1931, 1935
Duffin, R. J.....2003
Dumas, H. 2260
Duncan, W. G.....2139
Dunk, A. C.....1898
Dunkle, R. V.....2334
Dunn, J. S. C.....2313
Dzhanelidze, G. Yu.....1905
Dzunkovskii, N .N.....2160
Eastaway, K. G.....2184
Eby, R. E.....2135
Eckert, E. R. G.....2178
Eckert, W. J.....1861
Eckman, D. P.....2359
Edge, P. M., Jr....2239, 2240
Efsen, A. 2041
Ehlers, F. E.....2208
Eibling, J. H.....2243
Eichelbrenner, E. Z.....2255
Ellis, J. R.....1893
Ellison, R. W.....1881
Elrod, H. G., Jr.....2263
Engel, H. L.....1968
Epshtein, M. O.....2053
Ernst, G. C.....2055
Essenburg, F. 2149
Estrada, A. de la C.....1939
Ezekiel, F. D.....1929, 2238
Ezikashvili, O. S.....1921
Fanelli, E. 2050
Fanucci, J. B.....2219
Farber, E. A.....2311
Farquharson, J. 1955
Faupel, J. H.....1878
Favre, A. J.....2260
Fehrle, L. 1997
Fellow, M. A.....1889
Ferri, A. 2209
Fessler, H. 2032, 2034
Fitzpatrick, H. M.....2279
Foster, H. H.....2186
Forrez, G. 2366

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Franklin, R. E.....2369
Fraser, R. P.....2189, 2192
Frederick, D. D.....1873
Freudenstein, F. 1899
Fricke, C. L.....1941
Fuchs, H. 2373
Fuchssteiner, W. 2072
Galkin, M. S.....1978
Gaponov, A. V.....1915
Garabedian, P. R.....2180
Gardel, A. 2161
Gaviglio, J. J.....2260
Gerard, G. 2118
Geronimus, Ya. L.....1894
Gier, J. T.....2334
Gladwell, G. M. L.....2078
Glickstein, M. R.....2311
Goldberg, A. M.....2086
Goldin, R. 2121
Goldman, G. M.....2120
Goldsbury, J. 2268
Golecki, J. 2015
Golovnin, G. Ya.....1975
Goode, H. H.....1864
Gossi, A. 2098
Gough, M. N.....2287
Goulard, Madeline, ...2020
Govier, G. W.....2313
Grant, J. N. G.....2203
Greaves, M. J.....2127
Green, A. E.....2024
Green, A. P.....2150
Green, L., Jr.....2345
Greenberg, H. J.....2131
Greenspan, M. 2364
Gregg, J. L.....2331
Grigorian, S. S.....2220
Grinberg, G. A.....2080
Gross, J. F.....2321
Grossmann, G. 2021
Guenther, K. 2340
Gustafson, W. A.....2296
Guth, W. 2170, 2182
Gutowski, F. A.....2362
Guttkin, L. V.....2358
Gvozdkov, N. M.....2326
Haeussermann, W. 1963
Hagedorn, L. 1899
Hahn, E. Yu.....2175
Hain, K., ...1899
Haliburton, W. 2278
Hall, A. S., Jr.....1898
Hamming, R. W.....2146
Handlos, A. E.....2346
Happel, J. 2375
Harding, B. L.....1910
Harkleroad, M. F.....2279
Harkness, J. L.....2284
Harris, D. B.....1878
Hart, C. E.....1962
Hasimoto, H. 2253
Hassan, K.-E. 2267
Hausenblas, H. 2356
Hayashi, I. 2091
Hayashi, T. 2291
Hecht, C. E.....2314
Heller, J. P.....2381
Herr, R. W.....1953
Herrmann, G. 1989
Hertzberg, A. 2224
Hess, R. V.....2204
Hess, R. W.....2367
Hetenyi, M. 2017
Hetzel, K. W.....2370
Hicks, R. 2005
Hieke, M. 2006
Hill, J. D.....1886
Hill, R. 2152
Hill, W. A., Jr.....2211
Hirai, N. 2083
Hirschfelder,
J. O. 2318, 2348
Hodge,
P. G., Jr...2066, 2132, 2151
Hodges, A. J.....2223
Hofelt, C. 2187
Hoglund, B. M.....2342
Holdaway, H. W.....2273
Hollitch, R. S.....2298
Holman, C. J.....1971
Holmes, A. C.....2298
Holzbock, W. G.....1956
Hopkins, I. L.....2146
Hoppman, W. H. II....1987
Horne, W. B.....2140
Hornfeck, A. J.....1863
Houwink, R. 2000
Hoxton, L. G.....2307
Hubner, E. 1974
Huffington, N. J., Jr.....1987
Hughes, G. W.....1890
Hundy, B. B.....2150
Hunziker, R. R.....2322
Imsland, T. S.....1863
Ingebo, R. D.....2186
Inger, G. R.....2225
Ioanide, P. 1992
Irvine, T. F., Jr.....2178
Isaksson, A. 2142
Istomin, P. A.....1909
Ivashchenko,
N. N. 1940, 1951
Iyengar, K. T. S. R.....2122
Jack, J. R.....2325
Jackson, G. 2286
Jackson, T. W.....2303
Jaeger, C. 2162
Jain, B. K.....2042
James, E. W.....1969
Jarry, R. L.....2304
Jaynes, E. T.....2293
Johannin, P. 1884
Johnson, C. H. J.....2249
Johnson, D. P.....1886
Johnson, G. D.....2280
Johnson, R. E.....1850
Johnson, R. L.....2395
Johnston, G. W.....2138
Jones, J. J.....2202
Jones, Rebecca 1861
Jorgensen, L. H.....2230
Kaar, P. H.....2044
Kadoya, M. 1852
Kallas, D. H.....2168
Kamzolkin, V. V.....2274
Kanwal, R. P.....2231
Karlsson, K. I.....2075
Karpen, A. V.....2195
Kashiwada, Y. 2291
Kasprzhak, G. M.....1949
Katuzor, A. I.....2054
Katz, D. L.....2337
Katzen, E. D.....2211
Kauffman, J. F. ..2188, 2341
Kaul, R. K.....1988
Kay, J. M.....2315
Kekhain, A. 2236
Kell, C. 2199
Kempe-Nemm, A. A....1925
Kempner, J. 2097
Kendall, R. E.....1872
Kermicle, H. A.....1955
Kestin, J. 2324
Khokhlov, M. A.....1906
Khromeyenkov, M. F....1901
Kichigin, M. A.....2357
Kiokemeister, F. L.....1850
Kiper, G. 1899
Kiselev, A. A.....2174
Kitaev, B. I.....1928
Klimentov, P. P.....2379
Knuth, E. L.....2297
Kochanowsky, W. 2387
Koff, W. 2149
Komatsu, S. 2114
Komoda, H. 2262
Konishi, I. 2114
Koppe, E. 2007
Koranyi, I. 2116
Korst, H. H.....2217
Kosmowski, J. 2113
Kozhevnikova, V. N....2093
Kramer, M. O.....2250
Krasovskii, A. A.....1934
Krzyblocki, M. Z. v.....2176
Krzywoblocki, M. Z.....2296
Ku, C. L.....2087
Kubo, T. 2092
Kuehn, D. M.....2211
Kuhn, H. W.....1866
Kuhns, P. W.....2214
Kunin, N. F.....2148
Kunio, T. 2033
Kuranishi, M. 2004
Kurdyumov, A. A.....2094
Kursin, S. A.....2164
Kuznetsov, V. S.....1993
Lalos, G. T.....1879
Lamoreaux, W. E.....2377
Lampert, S. 2212
Larsson, H. 1918
Lassiter, L. W.....2367
Laurence, J. C.....2266
Lawden, D. F. ...1887, 1889
Layrangues, P. 2067
Leadon, B. M.....2343
Lefkowitz, I. ... .2359
Leist, K. 2290
Leitman, G. 1888
Leng, D. E.....1885
Leppert, G. 2342
Leven, M. M.....2031
Lew, H. G.....2219
Lewis, J. P.....2185, 2329
Lewis, P. 2394
Lichtman, J. Z.....2168
Lieberman, D. A., 1924, 1965
Lifschitz, Ya. D.....1892
Linnell, R. D.....2221
Lis, L. 2236
Litvin-Sedoi, M. Z.....1912
Livshits, I. E.....1907
Lo, H. 2020
Lobovikov, A. S.....2102
Loeb, J. M.....1922
Lomakin, L. M.....1928
Loo, T.-T. 2016
Lopez, A. E.....2193
Lordkipanidze, R. S.....1980
Luchak, G. 1868
Luft, L. 1883
Lukin, G. Ta.....2389
Lunchick, M. E.....2243
Lynch, F. W.....1942
Lysenko, B. M.....1993
Lyubatov, Yu. V.....1913
MacDermott, W. N.....2283
MacDonald, J. R.....2350
Machol, R. E.....1864
MacMillan, R. H.....1911
Madison, V. G.....1928
Madsen, J. 2299
Maeder, P. F.....2324
Makeev, A. N.....2374
Malkina, R. L.....2110
Mal'tsev, V. F.....1920
Malvern, L. E.....1979
Manning, G. K.....2145
Manning, W. R. D.....1877
Mansfield, E. H.....2079
Mantel, E. 2038
Marciniak, Z. 2002
Marx, A. J.....2288
Maslen, S. H.....2222
Mason, E. A.....2347
Matumoto, T. 2090
Mavis, F. T.....2127
May, A. 2213
Maze, R. A.....1972
McCracken, D. D.....1860
McDonald, P. H., Jr....2017
McDowell, E. L.....2026
McGregor, W. K.....1970
Mead, D. J.....1996
Meyer, R. C.....2210
Meyer, R. E.....2200
Mifflin, T. R.....2355
Miliukov, P. I.....2157
Miller, D. R.....2275
Miller, M. 2038
Milne, A. A.....2386
Minakov, A. P.....2039
Minassyan, R. S.....2046
Minkin, G. S.....2059
Mirsky, I. 1989
Mixson, J. S.....2240
Moeckel, W. E.....2222
Moore, C. C.....2394
Mori, H. 2388
Moseenkov, B. I.....1982
Mundry, E. 2170

(Continued on outside back cover)

INDEX OF AUTHORS REFERRED TO IN THIS ISSUE *(Continued)*

(NUMBERS USED ARE SERIAL NUMBERS OF REVIEWS)

Murdock, J. W.....2268
Murray, J. D.....2207
Myers, J. E.....2355
Naghdi, P. M.....2149
Nakagawa, Y. 2172, 2333
Nakaizumi, T. 2291
Nakamura, K. 2076
Nakamura, S. 2108
Nardo, S. V.....2066
Nazarov, O. O.....1859
Nehring, O. 2319
Neimark, Yu. I.....1950
Nemanic, D. J.....1971
Ness, N. 2232
Neville, A. M.....2147
Newhall, D. H....1871, 1880
Newland, P. L.....2383
Nightingale,
J. M. 1937, 1938
Nonweiler, T. 2323
Novik, D. 1962
Nowacki, W. 2028
Nowakowski, W. 2029
Nowinski, J. 2030
Obmorshev, A. N.....1984
Ohashi, M. 2114
Ohigashi, S. 2291
Ollerton, E. 2034
Olsen, O. J.....2115
Oshima, N. 2045
Ostrach, S. 2332
Owens,W. W. 2377
Pacelli, M. 2010
Paduart, A. 2011
Parmakian, J. 2163
Parrish, D. R.....2377
Parsons, D. H.....2344
Patel, S. A.....2097
Paul, B. 2132
Paulus, H. J.....2277
Payne, L. E.....1854
Paynter, H. M.....2238
Perret, W. 1917
Perzhnyanko, E. A.....1999
Pfeifer, W. J., Jr.....2299
Pfister, R. C.....1966
Pfluger, A. 2063
Pinadjan, V. V.....2048
Pindera, J. T.....2036
Pisarenko, G. S.....1976
Piszczek, K. 2043
Plockinger, F. 2190
Polozhyi, G. N.....2022
Polz, K. 1991
Poplavskii, R. P.....2080
Popov, E. G.....2159
Popov, I. G.....2104
Popov, Yu. N.....1897
Porter, R. L.....1873
Powell, R. L.....2316
Preissmann, A. 2382
Price, D. 1879
Priem, R. J.....2351
Probstein, R. F.....2308
Proskuriakov, A. K.....2155
Racicot, E. A.....2252
Radford, B. A.....2313
Radok, J. R. M.....2024
Ranz, W. E.....2187
Rayner, A. C.....2278
Reamer, H. H.....2310
Reshotko, E. 2258
Resler, E. L., Jr.....2365
Richardson, H. H.....2391
Richardson, J. T.....2115
Richter, G. N.....2310
Rickett, G. 2122
Riftin, L. P.....1853
Rivals, J.-L. 1986
Rivlin, R. S.....2024
Robertson, E. C.....1875
Robertson, J. M.....2264
Rofner, W. 1899
Roger, W. M.....2316
Rogozinski, M. 2001
Rohsenow, W. M.....2339
Rose, R. T.....2032
Rosenauer, N. 1899, 1908
Ross, J. F.....1882
Roth, J. P.....1851
Rothbart, H. A.....1959
Rothman, M. 2095
Roudebush, W. H.....2390
Rouggignac, C. 2179
Rubanik, V. P.....1977
Ruggeri, R. S.....2185, 2329
Ruglen, N. 2251
Russell, D. W.....1970
Ruth, R. F.....2261
Rvachev, V. L....2009, 2051
Ryabov, B. A.....1930
Ryley, D. J.....2302
Rzhanitsyn, A. R.....2143
Saaty, T. L.....1867
Saffman, P. G.....2183
Sage, B. H.....2310
Saito, A. 2083
Salekhov, G. S.....2378
Salemann, V. 2167
Salzer, J. M.....1973
Sanders, J. C.....1962
Sasaki, T. 2388
Savage, H. F.....2194
Savona, J. S.....2123
Sawaragi, Y. 2153
Schader, A. 2072
Scheule, D. E.....2362
Schnackel, H. C.....2301
Schnarbach, K. 1899
Schnitt, A. 2119
Schroder, R. 2165, 2271
Schuerger, T. R.....1964
Schwarz, N. 2191
Scott, C. J.....2343
Scott, D. S.....1851
Sekiya, T. 2082
Senoo, Y. 2254
Sergeev, M. A.....1946
Sharma, B. D.....2027
Shaushiashvili, A. M....2099
Shchitova, V. M.....1949
Shepard, B. M.....1876
Sherman, D. I.....2084
Sherrard, E. S.....1960
Shield, R. T.....2125
Shimanskii, Yu. A..2047, 2154
Shlyakhto, P. N.....2358
Short, B. E.....2354
Short, R. D., Jr.....2243
Shul'gin, M. F.....1914
Sibirsky, K. S.....1903
Siegel, R. 2330
Siemes, W. .2188, 2340, 2341
Silberman, E. 2181
Silsby, N. S.....2215
Silvestri, G. J.....2300
Simmons, J. C.....2371
Simons, R. M.....2071
Skuie, A. R.....2156
Sliepcevich, C. M. 1870
Slovinskii, V. A.....2109
Smiley, R. F.....2140
Smith, D. N.....1943
Smith, D. W.....2265
Soehrens, J. E.....2064
Sokolovskii, D. L.....2158
Solianik-Krassa, K. V...2052
Soo, S. L.....1958
Sparrow, E. M.....2332
Sretenskii, L. N...2246, 2247
Staab, F. 2270
Starshihov, K. K.....2103
Steeds, W. 1893
Steltz, W. G.....2300
Stern, E. G.....2137
Stevens, F. 1942
Stewartson, K. 2248
Suddarth, S. K.....2037
Sundstrom, E. 2101
Suray, S. 1857
Sutton, G. W.....2317
Svensson, N. L.....2065
Svirsky, M. S.....2148
Synge, J. L.....2019
Szelagowski, F. 2088
Tait, R. I.....2363
Tal, A. A.....1933
Talvitie, N. A.....2277
Tao, L. N.....2392
Taylor, C. F.....2327
Templin, R. J.....2289
Tewari, S. G.....1988
Thomas, F. A.....2303
Thomson, J. L.....1893
Thomson, W. T.....1923
Thornton, P. R.....2332
Tierney, J. W.....1971
Ting, L. 2209
Tinling,
B. E. 2193, 2194, 2195
Tokumaru, H. 2153
Toong, T. Y.....2327
Topcheev, Yu. I.....1947
Topping, J.....1865
Toriumi, I. 1990
Tosti, L. P.....2285
Traill-Nash, R. W.....1994
Tranin, I. I.....2144
Trbojevic, M. D.....1916
Treat, B. F.....2354
Tripp, W. 2217
Trostel, R. 2058
Tschiegg, C. E.....2364
Tsu, T. C.....2309
Tsurkov, I. S.....2073
Tsypkin, Ya. Z....1926, 1932
Tucker, M. 2258
Udoguchi, T. 2033
Unoki, S. 2245
van Itterbeek, A. 2366
Van Ness, H. C.....2321
Vannah, W. E.....1862
Vassiliev, G. A.....2112
Vekuya, I. N.....2074
Venkatraman, B. 2141
Vernon, L. M.....1870
Vick, A. R.....2196
Viswanadha Sarma,
L. V. K.....2173
Vittkup, E. B.....2012
Vodar, B. 1884
Vodicka, V. 2081
Volmer, J. 1899
Vorontsov, G. V.....2105
Wada, Y. 2082
Wahl, A. M.....2061
Wallis, R. A.....2251
Walther, R. E.....2111
Wahl, A. M.....2031
Wardlaw, R. L.....2289
Wasiutynski, Z. 2113
Wehrmann, O. 2276
Westmoreland, J. C.....2171
Whitney, C. S.....2128
Wigglesworth, L. A.....2096
Wilcock, D. F.....2396
Wildmann, M. 2393
Will, B. 1998
Williams, A. O., Jr.....1869
Williams, M. L.....2077
Wilson, A. H.....2292
Windels, R. 2069
Wisniewski, R. J.....2325
Wolf, R. C.....1874
Wolfe, M. O. W.....2368
Wolff, E. R.....2272
Wolko, H. S.....2119
Wong, R. E.....2134
Wood, W. W.....2227
Woods, L. C.....2281
Woolf, S. 2106
Wright, J. H.....2129
Yagi, Yu. I.....1904
Yakub, K. 2023
Yamaga, J. 2257
Yamaki, N. 2008, 2100
Yang, H. H.....2261
Yanpolsky, A. R.....2057
Yasuhara, M. 2226
Zartarian, G. 2218
Zavialov, K. D.....2155
Zemansky, M. W.....2295
Ziemba, S. 1985
Zil'berman, Y. S.....1896
Zimmerman, R. H.....2305
Zingerman, Yu. M.....1900
Zunnunov, N. Z.....1895